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No. 1

THE DISTRIBUTION SYSTEM OF THE CHICAGO WATER WORKS¹

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The Town of Chicago was incorporated in 1833, and the City of Chicago in 1837.

The earliest effort of record to provide a public water supply was made on November 10, 1834 when the Board of Trustees paid \$95.50 for the digging of a well. This well was located at what is now the intersection of Cass Street and Austin Avenue. As in the case of other town pumps of that period it was necessary for the citizens to come to the well for water.

It was soon realized that Lake Michigan was the most suitable source of water supply and for some years Lake water was distributed to householders by means of water carts.

In 1836 the Chicago Hydraulic Company was incorporated under authority granted by the State Legislature. Its charter was granted for a period of 70 years. The panic of 1837 interfered with the affairs of this company so that it was not until 1840 that operations were begun. In that year a reservoir 25 feet square and 8 feet deep, elevated about 80 feet above the surface of the ground, was built at Lake Street and Michigan Avenue. A 25-horse-power pumping

¹ Presented before the Chicago Convention, June 8, 1927.

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engine was used to elevate the water to this reservoir. The water was taken from Lake Michigan through an intake pipe which extended into the Lake to a point about 150 feet from the shore.

The water was distributed through wooden mains, these being logs bored out, 5 inches in diameter for the main lines and 3 inches for the subordinate lines.

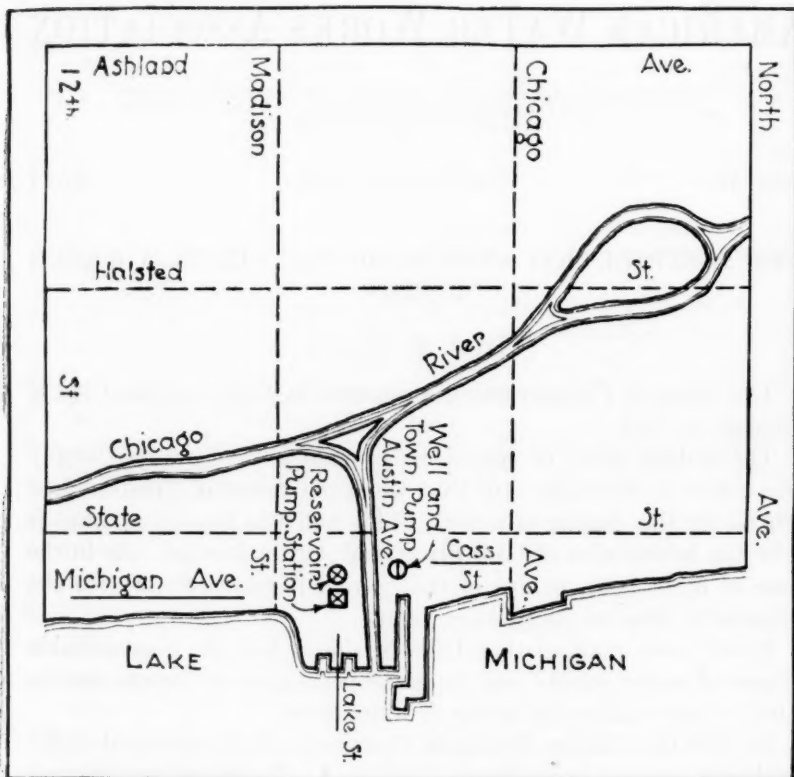


FIG. 1. LOCATION OF TOWN PUMP—THE FIRST MUNICIPALLY OWNED WATER SUPPLY, PUMPING STATION AND RESERVOIR OF CHICAGO HYDRAULIC CO.

This supply reached only parts of the city immediately south and west of the Chicago River, the north side being still supplied by means of water carts and wells.

The Chicago Hydraulic Company operated until 1852 when its franchise was taken over by the City of Chicago as a result of a legislative act passed February 15, 1851.

The first municipally owned pumping station was built at Chicago Avenue and the Lake Shore. The famous water tower which was built in connection with this station was completed in 1867. The supply of water was taken through a 30-inch wooden pipe extending into the Lake about 600 feet, and pumping operations were commenced in 1854. The water was distributed through cast iron pipes and from three reservoirs located as shown herewith.

Each reservoir held about 575,000 gallons. The reservoirs were of wrought iron, being built upon a masonry and brick foundation so that their tops were 80 feet above the surface of the Lake. These reservoirs served to equalize the supply and to meet the fire draft.

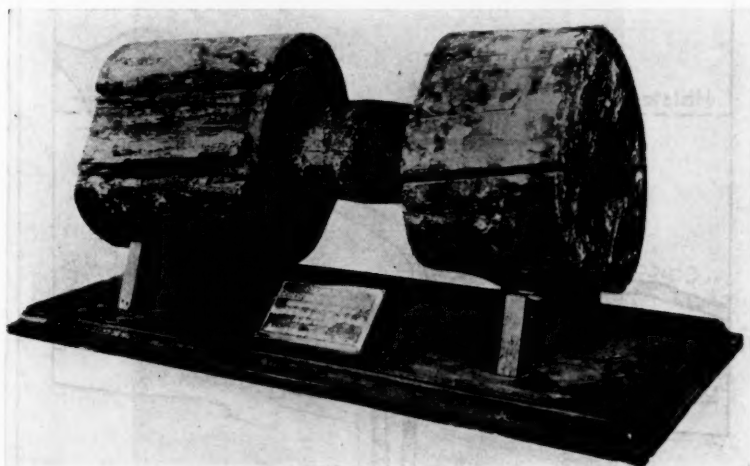


FIG. 2. WOODEN PIPE USED IN CHICAGO FIRST WATER DISTRIBUTION SYSTEM LAID IN 1840, TAKEN OUT OF N. CLINTON STREET, BETWEEN KINZIE STREET AND CARROLL AVENUE

The reservoir at La Salle and Adams Streets was badly damaged by the great fire of 1871 and was never put back in service after the fire. The last of the three reservoirs, the one at Morgan and Monroe Streets, was abandoned in 1876 and since that year the system has been one of "direct pumping."

The first cast iron distribution pipe was 4 inches in diameter and was laid in Clark Street in 1852. This marked the beginning of the rapid development of the water distribution system that followed. From 1852 to 1862, 105 miles of cast iron mains were laid. At the end of 1862 the population was about 140,000 and the average daily

pumpage was 7,000,000 gallons or at the rate of 50 gallons per day per capita. The area of the city at that time was about 20 square miles.

All of the original feeder mains shown, except the wrought iron river crossings, are still in service and in good physical condition. A

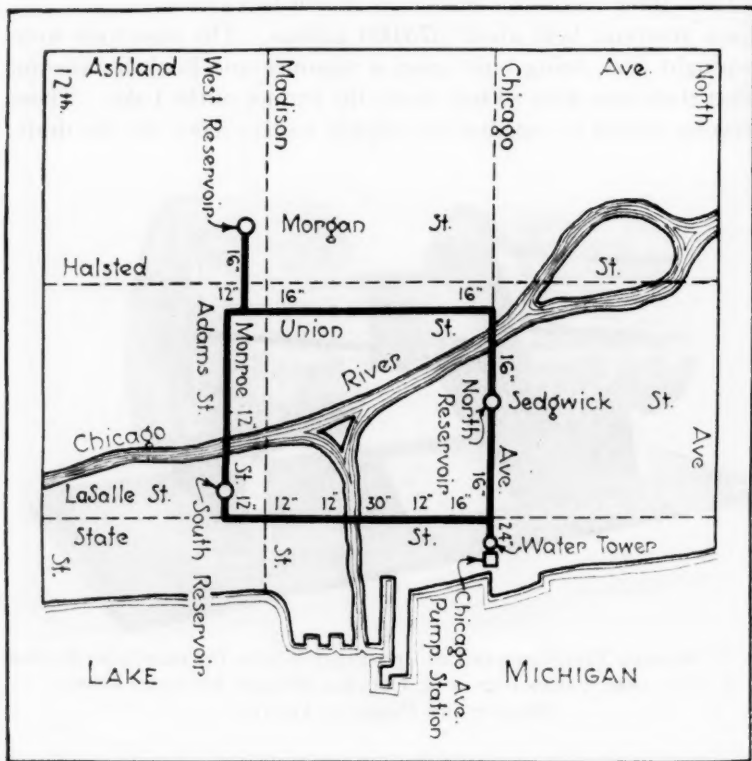


FIG. 3. LOCATION OF FIRST MUNICIPALLY OWNED PUMPING STATION AT CHICAGO AVENUE AND THE LAKE SHORE AND PRINCIPAL WATER MAINS AND RESERVOIRS OF THE ORIGINAL CAST IRON DISTRIBUTION SYSTEM OF CHICAGO

piece of the original 12-inch pipe laid in Adams Street near Clark Street was recently taken up.

The great fire of 1871 destroyed all of the atlases showing the locations of mains and service pipes. Some 15,000 lead service pipes

were melted during the fire, causing a great deal of leakage which was difficult to locate because the records had been burned.

The growth of the city was rapid previous to 1889, and that year vast areas were annexed, the principal of these being the

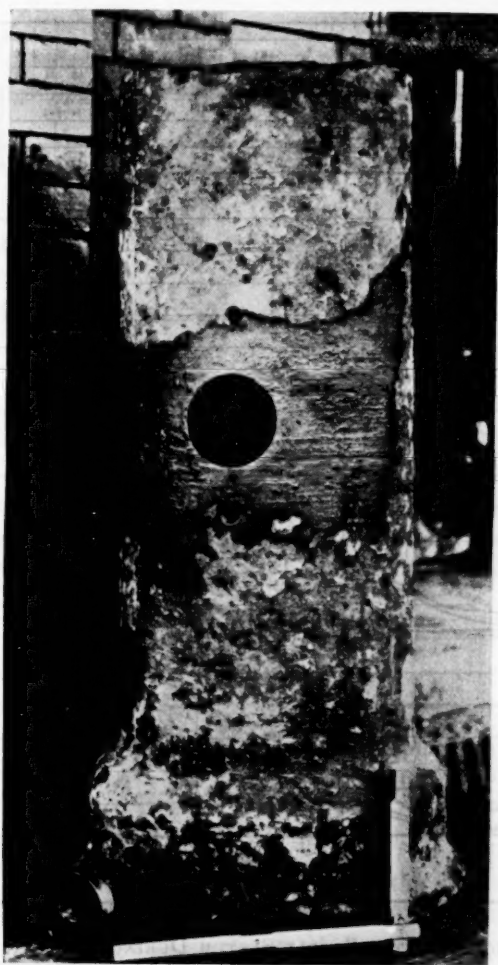
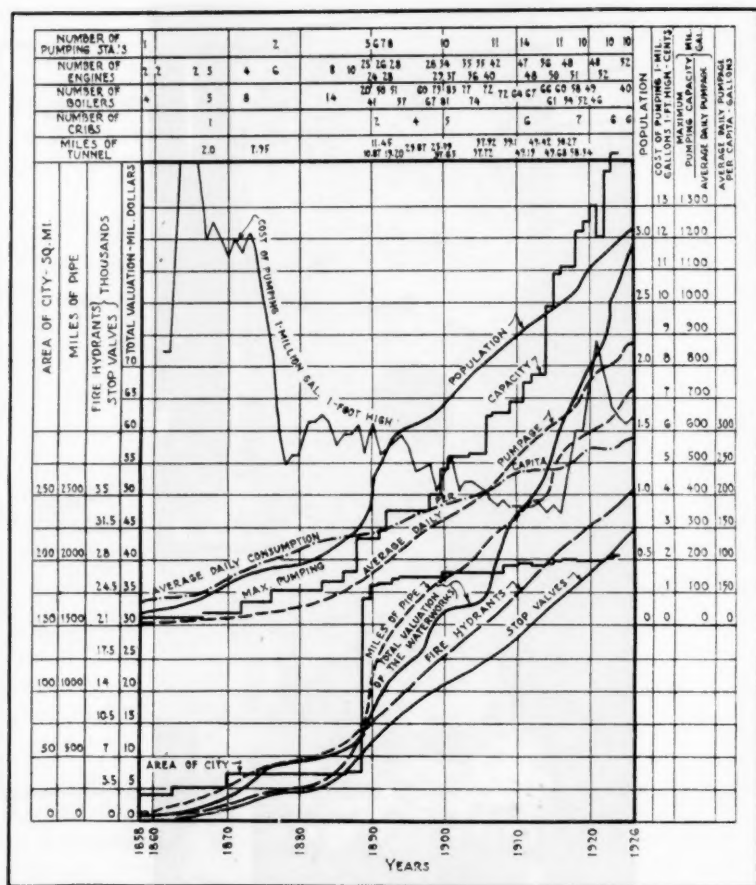


FIG. 4. SECTION OF 12-INCH PIPE TAKEN OUT AT ADAMS AND CLARK STREET
(First 12-inch cast iron pipe laid)

towns of Lake View, Hyde Park and Lake, each of which had water systems entirely independent of the original Chicago system. These annexations increased the area of the city from 36 to 170

square miles. The problem of unifying the various water systems occupied considerable time, much of this work being done from 1890 to 1900. In 1898-1899 a special effort was made to connect up the various systems and 55 miles of large feeder mains were laid for



population, including that of outside communities supplied, of approximately 3,300,000. The water system consists of 11 major pumping stations, including the new Wm. Hale Thompson Station, 6 cribs, 66.84 miles of tunnels, 3,340 miles of cast iron mains, 35,505 hydrants and 31,130 gate valves. The maximum pumping capacity is 1,560 m.g.p.d. and the average daily pumpage is 878,000,000 gallons. The average daily per capita consumption within the city limits is 286 gallons. The water system is valued at \$90,315,000.00.

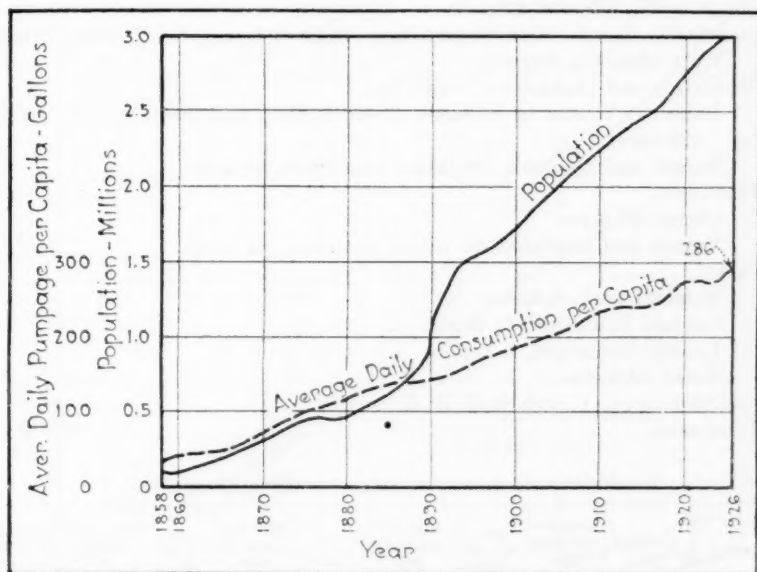


FIG. 6. POPULATION AND AVERAGE DAILY CONSUMPTION PER CAPITA—CITY OF CHICAGO, YEARS 1858 TO 1926 INCLUSIVE

PROBLEMS IN DESIGN

Owing to the rapid growth of the city and the ever-increasing per capita consumption, the engineers have faced many intricate problems in designing extensions to the water distribution system. However, these problems have been greatly simplified by the introduction of instruments such as the pitometer, by means of which slippage of pumps and the velocity of flow in existing mains can be determined. During the past 20 years pitometer surveys have been made at intervals to determine the conditions under which the feeder mains

were working. Results of such surveys have been used in making recommendations for extensions to the feeder and distribution mains.

Previous to the introduction of velocity measuring instruments, the static pressure gauge was used to determine the head loss in any

TABLE 1
Typical Occupational Survey Sheet

Section 17. Township 38N. Range 14E.

Plat nos. 461, 462, 478, 479.

Boundaries: North—55th Street; East—Halsted Street; South—63rd Street; West—Ashland Avenue.

Population and character of buildings:

Buildings consist of cottages, 2 and 3 flats, and residences occupying 523 acres.

Vacant and available for future residences, 60 acres.

Factories:

Occupy 10 acres.

Vacant and available for future factories, 14 acres.

Parks:

Baseball park, 4 acres.

Garfield Boulevard, 12 acres.

Loomis Boulevard, 8 acres.

Total, 24 acres.

Railroads: P. C. C. and St. L. R. R., 9 acres.

Total area 640 acres

Estimated maximum rate of water consumption

YEAR	POPULATION	MILLION GALLONS PER DAY	AREA FACTORIES	MILLION GALLONS PER DAY	AREA PARKS	MILLION GALLONS PER DAY	AREA RAILROAD	MILLION GALLONS PER DAY	TOTAL MILLION GALLONS PER DAY
1920	31,435	9.4	9	0.2	24	0.1	9		9.7
1925	33,200	13.3	12	0.25	24	0.1	9		13.7
1930	35,000	14.0	16	0.3	24	0.1	9		14.4
1935	36,500	14.6	19	0.4	24	0.1	9		15.1
1940	38,000	15.2	23	0.4	24	0.1	9		15.7

Date, September 11, 1925. Study by H. L. Approved by J. L. I., District Engineer.

main or system of mains. This method was somewhat uncertain, in that large underground leaks, partly closed valves, or pump slip-page might exist and losses due thereto be undetermined.

The velocity measuring instruments and static gauges are now in

use continuously as aids in determining the conditions under which the distribution system is being operated, and as aids in determining where extensions to the system are needed. Permanent pitometer gauging points have been established on feeder mains throughout the entire distribution system at intervals of about one mile. These are available whenever it is considered necessary to make a check-up of the operating conditions on any feeder main.

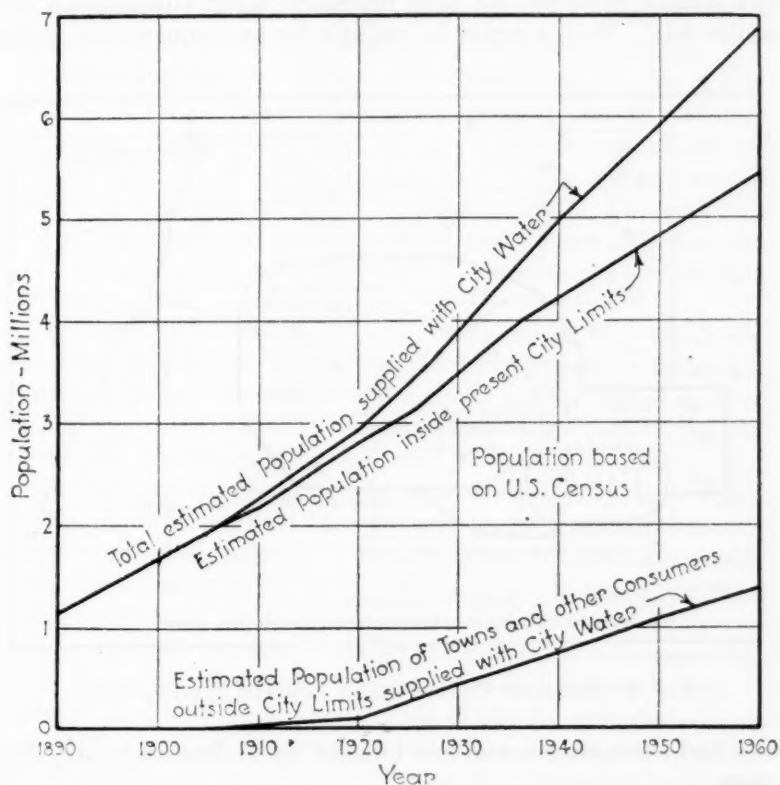


FIG. 7. INCREASE IN POPULATION SERVED

The square mile has been used as the unit in making closed pitometer surveys and in making occupational inspections. A report of such an occupational survey is shown in table 1. This report shows the population and character of buildings and the number of acres occupied by factories, parks and railroads. In the tabulation there is shown the population as taken from the United States census for

the year 1920 and the estimated population for each five-year period up to 1940. The amounts of water shown as consumed in the square mile area for 1920 are taken from pitometer tests. The estimated quantities for the five-year periods up to 1940 are based upon the population increase and the per capita rate as determined from pitometer surveys. The next column shows the area occupied by factories and the amount of water used for industrial purposes. In the last column is shown the total maximum water consumption per square mile. Such a report is available for each square mile in the

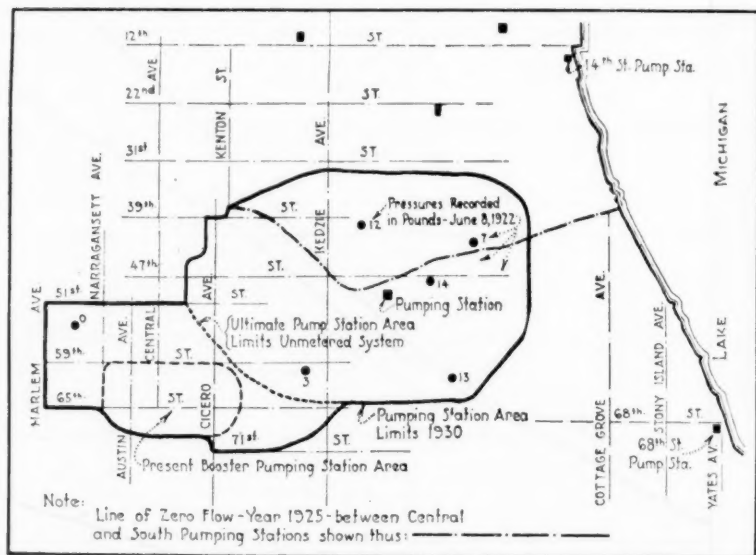


FIG. 8. HYDRAULIC CONDITIONS IN PUMPING STATION AREA

city and these are checked and brought up to date once every five years.

The population is studied by square miles and population curves are plotted for past and for estimated future population in each square mile. A population curve for the entire city has been projected forward to the year 1960.

The static pressure records, occupational surveys, population estimates and square mile pitometer surveys are used in determining estimated future water requirements which are used in designing

extensions to the water system. The manner of applying these data to design can be shown by giving a few facts concerning the new Wm. Hale Thompson pumping station.

The pressures in the zone crossing the city from east to west between 31st Street, and 63rd Street have been decreasing for years past. The pressures shown were recorded on June 8, 1922, or five years ago. The pressure at 55th Street, near the west city limits dropped to zero, and at a point $4\frac{1}{2}$ miles east of the west city limits near 60th Street the pressure reached 3 pounds as a minimum.

Pitometer gaugings for the year 1922 showed that the line of zero flow between the central and south side pumping stations was near 43rd Street. The zero flow line as shown was determined by pitometer gaugings made during the year 1925. This line had moved slightly south of its position as recorded in 1922. The pressures taken in 1922 indicated that in a great part of this vast area the water supply had reached the point of exhaustion, showing that reinforcement was overdue.

In considering the location of the pumping station from which this area should be supplied with water, the first step was to determine the normal limits of each of the old stations north, east and south of the proposed station, that is, the line distant from each of the old stations where each could deliver with its existing equipment and through the existing feeder mains not less than 25 pounds static pressure at the street level during the hours of maximum demand. In determining these lines about the old stations, a reserve of approximately 25 per cent in pumping equipment was allowed, and the maximum allowable head loss from friction in the feeder mains was taken at 5 pounds per mile, which for the system, as interconnected, allows of a maximum velocity of approximately 5 feet per second.

After a careful study had been made of the old pumping station areas with regard to their present and future requirements, points were spotted on the map which fell near the Drainage Canal and 35th Street on the north, Stewart Avenue on the east, and 63rd Street on the south. A line was drawn through the points so determined and made when connected with the west city limits a closed area, thus determining the proposed pumping station area. The dotted line in figure 8 indicates the ultimate boundary for an unmetered system.

A careful study of each square mile within this proposed pumping station area was made. The occupational surveys were checked and

all industrial and residential occupation noted. Estimates were made of the amount of future occupation for both residential and industrial purposes.

Pitometer surveys had been made in each square mile and the per capita rates for each thus determined. Industrial requirements were determined by reading the meters of each industry 24 hours or longer, thus deriving a characteristic curve for each. Population records for past years were plotted and projected into the future. A special study was made of the Stock Yards and Packingtown requirements.

Maximum daily water consumption estimates were arrived at for each square mile and, when added up, totalled 217 million gallons per day for the year 1930.

Considering the station area as described, it was found that the center of load (exclusive of the Stock Yards) for the year 1922 fell at 43rd and Robey Streets. That part of this area northwest, north and northeast of the center of load is practically all occupied by industrial plants. The area south and southeastward is mostly occupied by residences. The area westward and southwestward has much vacant property, part of which will develop into industrial and part into residential occupation. The center of load will therefore move more slowly southwestward until all the vacant property is occupied or until the maximum limit of the station capacity has been reached.

A line drawn southwest from the center of load as established for 1922 fell through the intersection of 47th Street and Western Avenue, and on account of transportation facilities, ideal get-away for feeder mains and land values, 49th Place and Western Avenue was chosen as the best location for the new pumping station. The center of load will always be near this point and this will make possible fairly low operating pressures.

The feeder main system was designed so that the Stock Yards and Packingtown with their great peak load can be isolated, if this becomes desirable. The header system at the station was also designed to make this isolation of the Stock Yards and Packingtown possible with no interference to the remainder of the service.

There are five 48-inch feeder mains radiating out from this station which connect with the older feeder mains of smaller diameter. Three of these large feeder mains bear directly upon the Stock Yards connecting feeders and on the feeder mains which supply the sections north, east and south of the Stock Yards.

The 48-36-30-inch main laid south and west of the station will

furnish water to a section which very often in the past few years has been entirely without pressure for fire or domestic purposes. This main supplies the highest point in the station area.

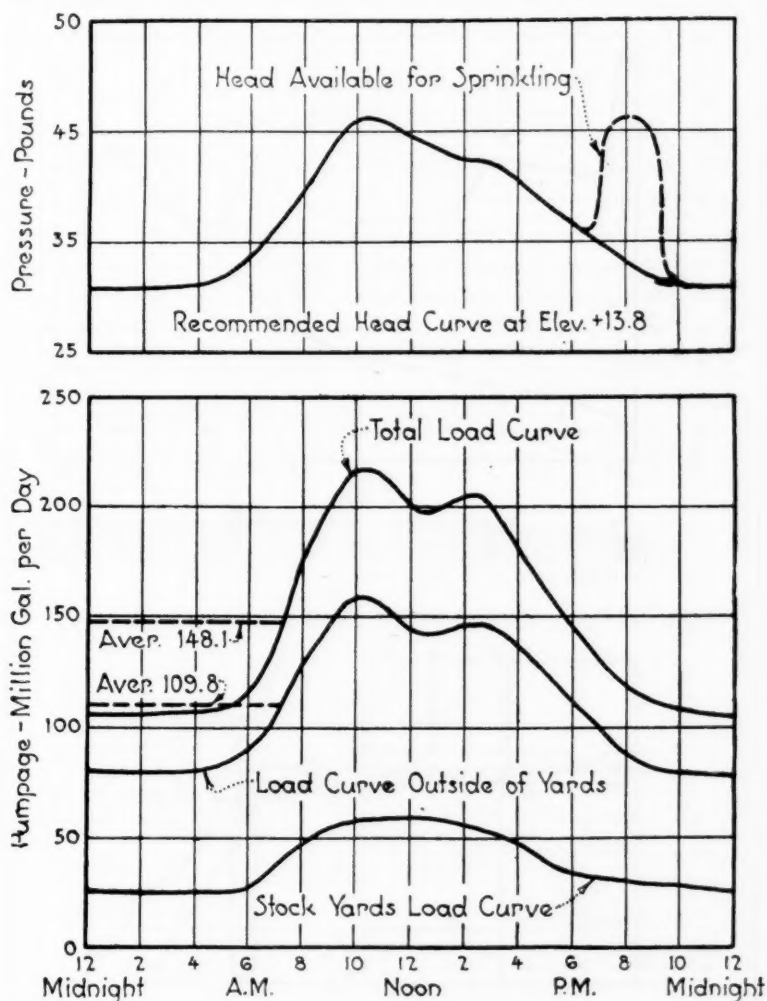


FIG. 9. HEAD AND LOAD CURVES—PUMPING STATION AT 49TH PLACE AND WESTERN AVENUE

The 48-36-inch main northwestward from the new station will supply a rapidly growing industrial section and will also furnish fire

protection and domestic supply for the section in this area north-westward to the Drainage Canal.

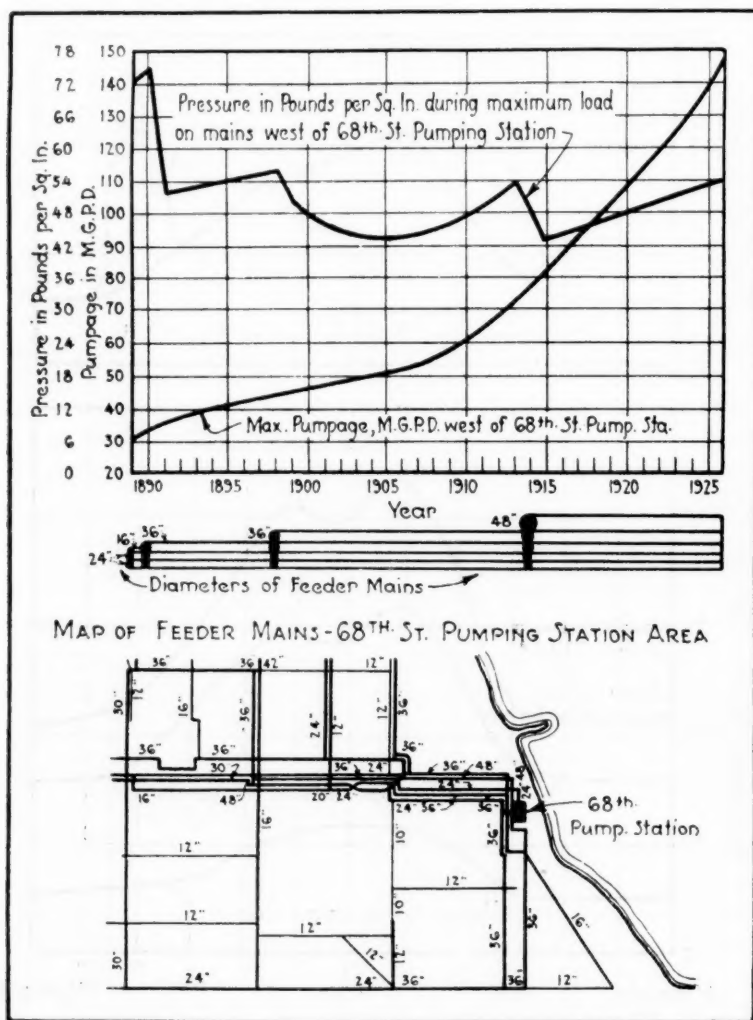


FIG. 10. DIAGRAM SHOWING 68TH STREET PUMPING STATION PRESSURE, MAXIMUM PUMPAGE AND SIZE OF FEEDER MAINS WEST OF THE STATION

Because of the small difference in elevation (about 20 feet) in street grades throughout this pumping station area, a one-head

station has been designed. Equalization of delivered pressures has been assured in the design of the feeder and distribution mains.

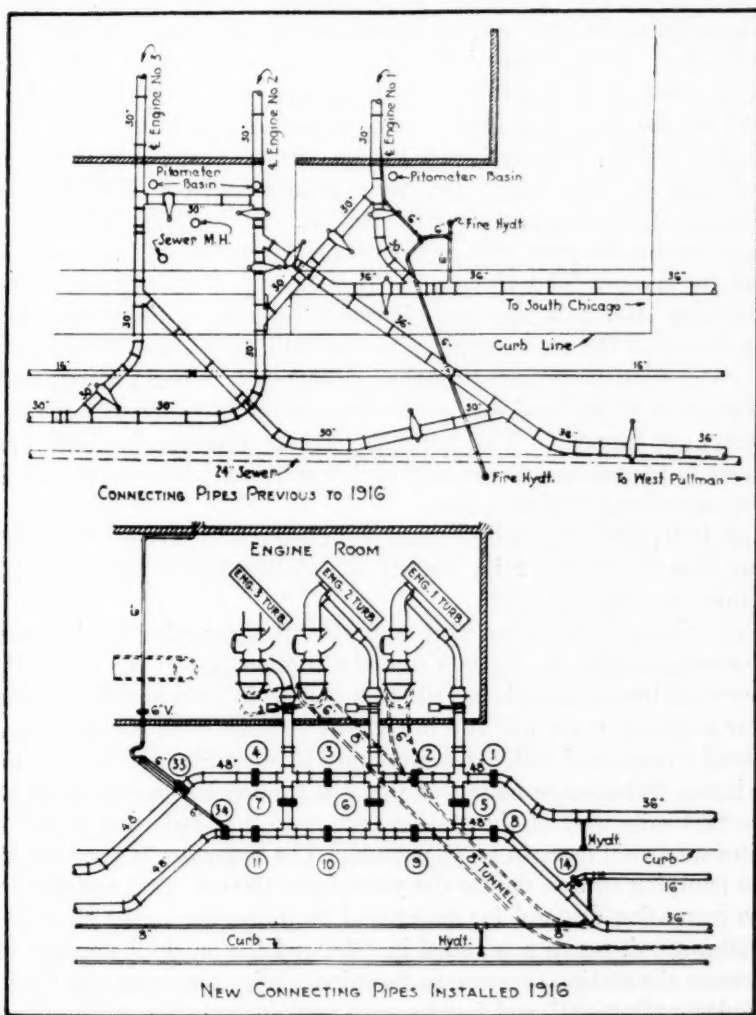


FIG. 11. REARRANGEMENT OF CONNECTING PIPES, 68TH STREET PUMPING STATION

The development of the feeder main system westward two miles from the 68th Street station serves to illustrate a problem met with

in attempting to keep "one jump ahead" of the rapidly increasing demand for water.

The 68th Street pumping station became a part of the Chicago Water System in 1889 with the annexation of the towns of Hyde Park and Lake. Being situated on the Lake Shore, a greater part of the water must be pumped westward. When this station was taken over by the city, three feeder mains extended west from the station in 68th Street to Stony Island Avenue, thence north to 67th Street and west in 67th Street; two were 24-inch and one a 16-inch in diameter in the 2 miles west of the station. In the report of the City Engineer for the year 1890, in discussing this system of feeder mains and the reasons for replacing the 16-inch with a 36-inch main, the following statement appears: "Pressure tests at hydrants revealed the fact that the main supply pipes on 68th Street, and 67th Street . . . were inadequate to such an extent that, to begin with, about 40 per cent of the head was lost in them on the first mile, before they were ever tapped." The pumping station pressure in 1890 was about 75 pounds and 40 per cent of this or 30 pounds in one mile was *some* considerable friction loss.

In 1891, after the 36-inch main had been put in service, the pressure loss in the first mile west of the station was 5 pounds or 25 pounds less than in 1890.

The demand for water west of 68th Street pumping station was increasing rapidly in the 90's and the friction loss in the first mile increased from 5 pounds in 1891 to 9 pounds in 1898 and during this year a 36-inch main was laid in Oglesby Avenue, 67th Street, Stony Island Avenue and 66th Street westward to State Street. The result of laying this 36-inch main was that the friction loss was reduced in the first mile west of the station from 9 to 2 pounds and in the 2 miles westward from 14 to 3½ pounds. The reduction in pressure at the pumping station during the years from 1900 to 1906 was due to the increasing demand for water and to increasing pump slippage. A 20-m.g.p.d. pump was added in 1906 and this made it possible to increase the station pressure as recorded. Slip tests were also made regularly after 1907 and pumps were kept in better condition than previously to that time.

A survey of this system of feeder mains was made in 1907 at which time the loss in the first 2 miles west of the station was about 11 pounds.

Again in 1913 a survey revealed that the head loss in the first 2

miles had increased to 15 pounds, the loss in the first mile west of the station being about 8 pounds, including entrance losses at the station. The pumping station pressure at this time was about 54 pounds during maximum load.

In 1914, to overcome the excessive friction loss and to provide an outlet for new pumps, a 48-inch main was laid from 68th Street pumping station westward in 67th Street to Cottage Grove Avenue. The result was that the friction loss in the mains westward from the station 2 miles was cut from 15 to 5 pounds. At this time, 1914, the maximum pumpage west of 68th Street station was at the rate of 77 m.g.p.d. This has increased until late in 1926 the pumpage westward from the station was at the rate of 150 m.g.p.d. The friction loss has again increased in the feeder mains in the first 2 miles west from the station from 5 pounds in 1914 to 15 pounds in 1926 and the pumping station pressure has been increased during the same period from 43 pounds to 54 pounds. It has been necessary to increase the total pump capacity at 68th Street pumping station from about 75 in 1905 to about 175 m.g.p.d. in 1926, and the tunnel capacity has also been correspondingly increased.

The friction loss has again become excessive, but when the Wm. Hale Thompson pumping station is placed in operation the requirement placed upon the 68th Street station will be materially reduced, and the result will be a marked decrease in the friction loss in this system of mains west of 68th Street pumping station. The friction loss will again fall within what is considered the economic limit.

THE EVOLUTION OF PUMPING STATION HEADER PIPES IN CHICAGO

In years past when a pump was added to the equipment of a pumping station, a connecting pipe was laid and cross-connected to the existing pipes at the station. Thus there gradually grew a number of pipes interconnected.

This arrangement of pump connecting pipes gave no end of trouble and great loss of head resulted therefrom at the station because valves were often broken when closed, or closed and left down. This old system at 68th Street station was replaced in 1916 by a new header system, thereby reducing the friction loss very materially.

A similar operation was carried out at Chicago Avenue pumping station in 1920. The famous water tower enclosed a steel standpipe which was a part of the old system of connecting pipes at this station.

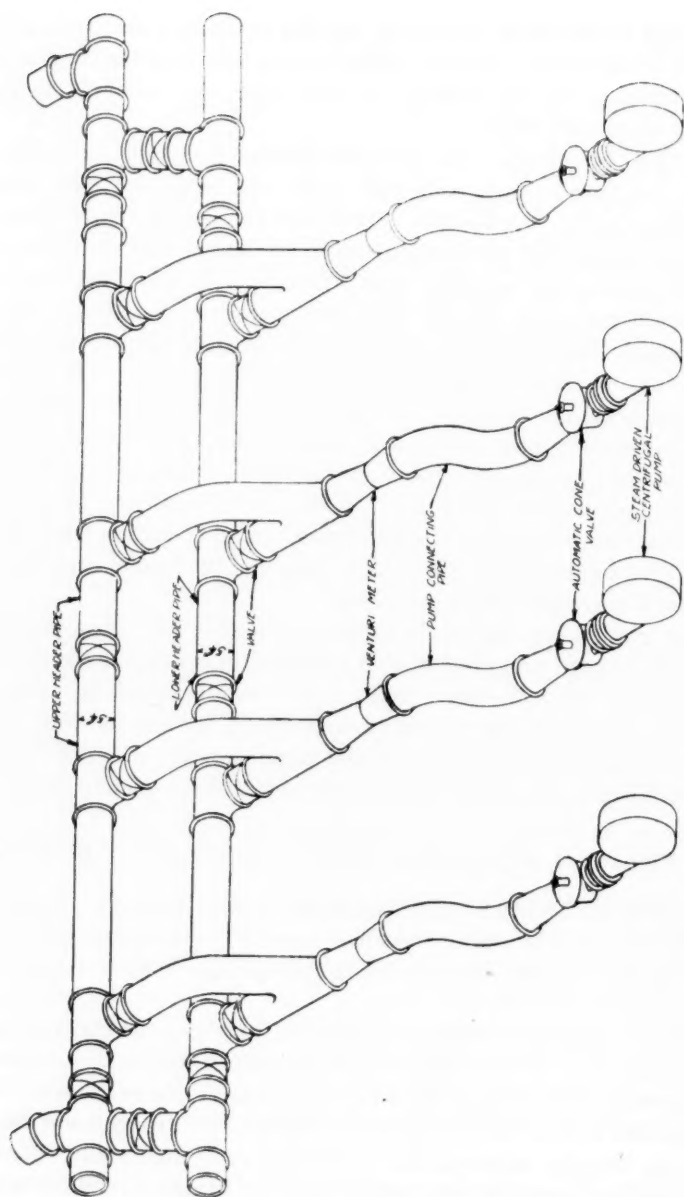


FIG. 12. PUMPING STATION HEADER AND PUMP CONNECTION PIPES

A condition with regard to frictional loss existed at the Chicago Avenue station similar to that which existed at 68th Street station with the old arrangement of connecting pipes. The new system has fewer complicated connections and less frictional resistance than the old, and like the one at 68th Street station has the header pipes in the same horizontal plane.

The 22nd Street station connecting pipes are still as originally installed except for a steel standpipe and brick tower recently removed. This system has very little flexibility. If the station is

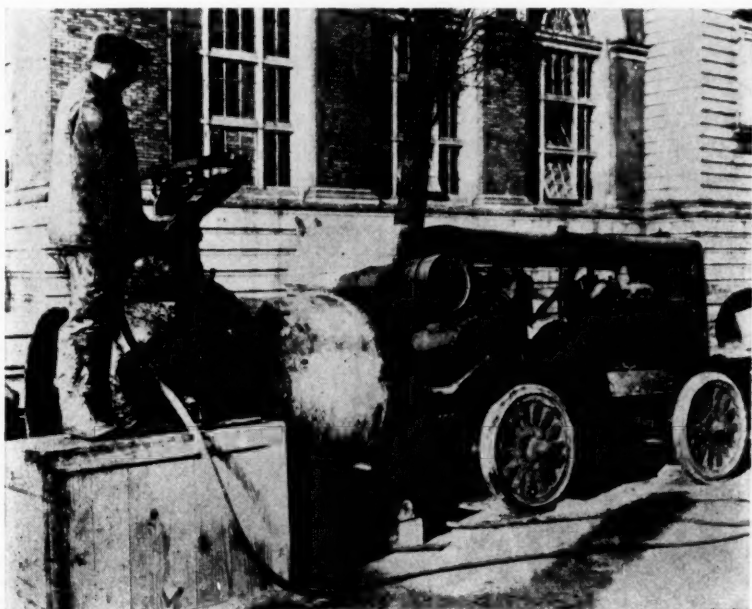


FIG. 13. AIRDRILL PIPE CUTTING MACHINE SHOWING AIR COMPRESSOR AND CONNECTIONS

shut down for any purpose very little water can pass from north to south or the reverse. As soon as the new Wm. Hale Thompson pumping station is placed in service steps will be taken to replace the pump connecting pipes at this station with a new system of header pipes.

The Wm. Hale Thompson station header system is considered a great improvement over the systems at 68th Street, Chicago Avenue and 22nd Street stations. The header pipes at this station are in two

horizontal planes separately connected to the pump pipe and valved so that each can be isolated without interference with the other. The valve control is electrical. Any valve can be closed or opened by the operating engineer by keyboard control. The operating engineer has a diagram before him which shows clearly the header and valve layout and the number of each valve.

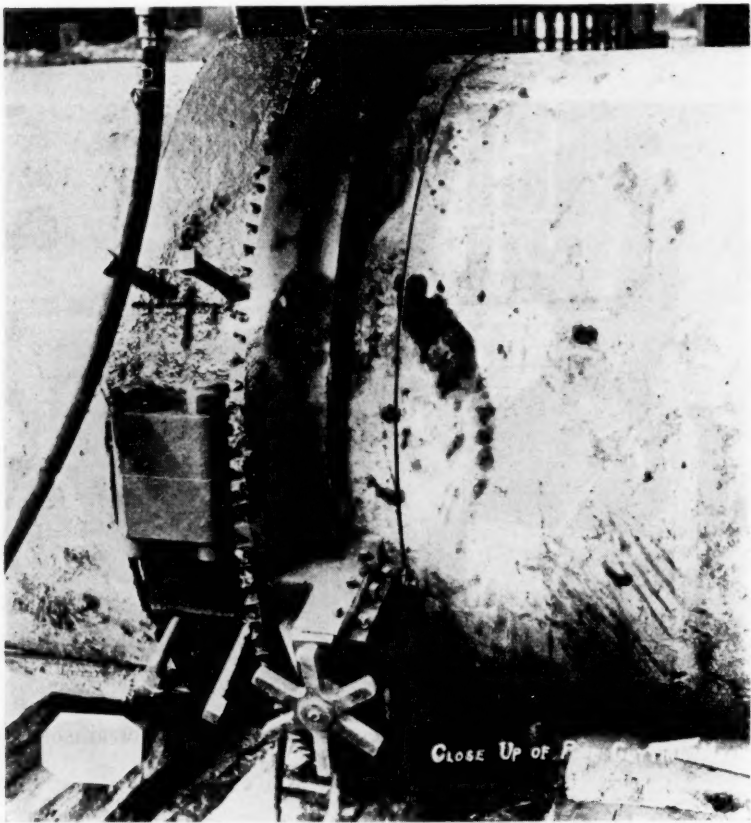


FIG. 14. CLOSE-UP OF PIPE CUTTING MACHINE ON 36-INCH PIPE

CONSTRUCTION AND MAINTENANCE

Construction and maintenance of the water distribution system are handled by a City Hall headquarters section and 3 field district sections.

During a period of a year 8,000 leaks are reported and repaired by

the maintenance force. These leaks are found on mains, service pipes, hydrants, valves and miscellaneous. For the year 1926, leaks were reported and repaired as follows: 5,081 service pipe leaks, 2,488 leaks on mains and 720 leaks on hydrants and valves.

Large feeder mains are constructed by power-driven equipment. Two No. 60 Austin trenching machines are used to excavate trenches. A 5-ton Erie steam crane and a Model No. 105 Northwest gas crane are employed for the handling and setting of pipe. Bell holes are dug with air clay spades. Calking is done with pneumatic hammers. Compressed air is furnished by an Ingersoll-Rand type No. 20, 160 cubic feet per minute capacity air compressor.

Trenches for smaller service and distribution mains are usually dug with machines. Three Parsons No. 30 and one Austin No. 00-28 machines are used for this work. Small pipes are cut, laid and calked by hand. About 66 percent of all pipe laying is done with power-driven equipment. Such equipment was introduced in the City of Chicago in the year 1912.

Backfilling of ditches and removal of surplus dirt on large pipe jobs are done by contract.

Machines are used for cutting pipes 30, 36, 42, and 48 inches in diameter. The pipe cutting machine is made up of a split sleeve which fits the pipe and is correctly adjusted thereto by the use of set screws, so that the same machine can be used to cut 30- and 36-inch pipe, while a larger machine of the same type is used to cut 42- and 48-inch pipe.

Attached to the top part of the split sleeve is a bracket upon which is mounted shafting and gears through which power is applied from an air drill to the cutter collar which revolves about the pipe. A non-reversible Thor close-quarter No. 9 air drill is used. Two cutter tools, set at 180 degrees to each other, are mounted on the cutter collar. These tools are No. 22 Armstrong with tool holders of the same make. As the collar turns about the pipe the cutters are adjusted to the surface thereof and as rotation continues the cutters are automatically forced against the pipe. It is first necessary to round up the pipe as nearly all pipes are slightly elliptical in shape.

The cutting tools must be made of high speed steel ground and set right and left so that they cut clearance as in a crosscut saw. Tools must be kept sharp and properly ground. An ample supply of tools should be kept on the job. The machine must be properly set so that no shifting, binding or misalignment can occur. The frictional

adjustment of the automatic feed must be accurately set so that the tools do not back up or chatter after passing the stop which automatically forces them against the pipe. If these directions are observed excellent results can be obtained with a pipe cutting machine and large pipes can be cut at greatly reduced cost as compared with

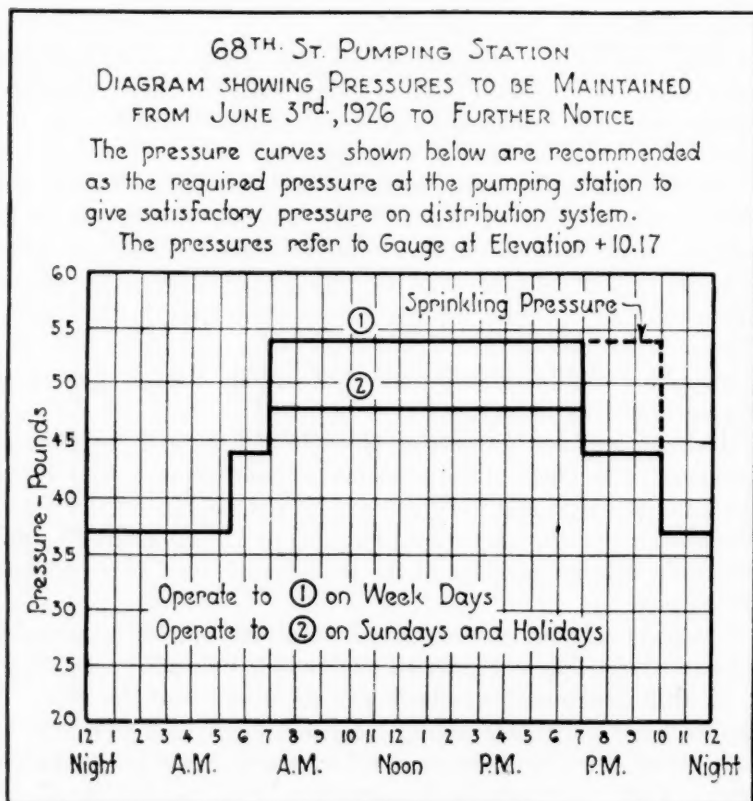


FIG. 15

hand cutting. A large saving in pipe is also effected by the use of a cutting machine.

When large service pipes are laid the tapping of the street main is usually done by means of a power tapping machine. About 400 such taps are made each year ranging in size from 3 to 12 inches. The pieces of pipe cut out are returned to the engineer and are tagged with

the location of cut, size of main, year laid, and date cut was made, and are kept for future reference. These pieces cut out indicate that, in general, the physical condition of the mains is excellent even after many years of service. Little tuberculation or encrustation is caused by the Chicago water. The pieces were cut from pipes in various locations of the city and range in age from 21 to 52 years. They show little or no corrosion.

All pipe lines constructed 16 inches in diameter and larger are treated with chlorine and a report stating that the quality of the water is satisfactory is necessary before a main is placed in service.

Where breaks occur and there is a possibility of contamination from surface water or from sewage, it is necessary to chlorinate and receive a favorable report from the Division of Water Safety Control before the main is returned to service.

OPERATION OF THE DISTRIBUTION SYSTEM

A system of pressure control has been in effect in Chicago during the past 12 years and has worked very successfully. This control tends to equalize the distribution pressures. By control of the connections between the feeder and distribution mains it is possible to decrease the pressures adjacent to and increase the pressures at points more distant from the pumping stations. To aid in the pressure control and give daily information as to pressure conditions, 62 static gauge stations are maintained in fire engine houses and pumping stations throughout the city. Records from these gauges are mailed daily to the District Engineer, who has pressure curves plotted for each weekly period. These pressure curves are forwarded to the City Engineer's office and placed on file. Thus an accurate record of past and present pressure conditions is always available.

The operation of controlling pressures requires considerable time in the summer season as it is necessary to change valve settings to meet changing weather conditions. In controlling any area close attention is given to the requirements for fire flow, and no section is so controlled that the fire flow is lowered below the requirements of the National Board of Fire Underwriters. Fire flow tests are made at frequent intervals, and reinforcement made where necessary to maintain the standard referred to above.

Pressure control curves upon which the pumping stations are operated have been worked out. It is necessary in preparing these

control curves to take into consideration the velocity of flow in the feeder mains for all hours of the day and the total head loss to the most distant point in the pumping station area. It has been possible to reduce greatly the night pressure which reduces the pumpage and

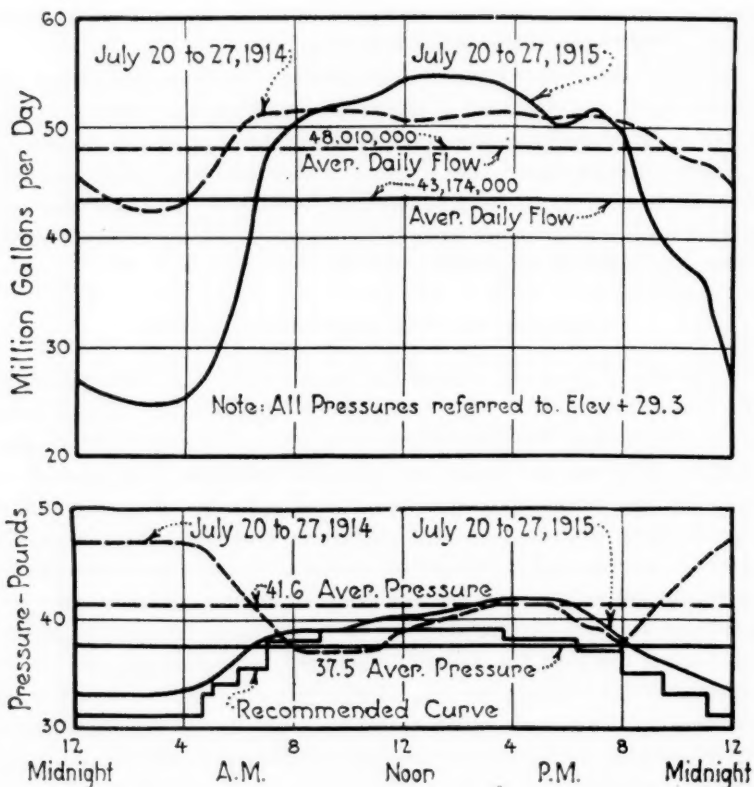


FIG. 16. EFFECT OF PRESSURE REGULATION AT ROSELAND PUMPING STATION

still deliver on the distribution mains sufficient pressure for all purposes.

Roseland pumping station was placed under control during the year 1915. The results of this control are shown in figure 16. The effect of this control was to lower very materially the night pressure and the night pumpage.

UNDERGROUND STREET LEAKAGE

The question is often asked: "How much of your pumpage is lost in underground street leakage?" The answer to this question cannot be accurately made, but an approximation of the amount can be arrived at. Below there will be outlined briefly what has been and what is being done to determine and stop underground street leakage in Chicago. From 1907 to 1912 inclusive a number of engineering parties were at work making pitometer surveys, a part of which work consisted in the detection and stoppage of underground leakage. In the older sections of the city many large underground leaks were located and stopped. The Loop district was partially covered by tests for underground leakage. In a number of streets

TABLE 2

Summary of results of underground leakage tests made in connection with street paving from 1916 to 1926 inclusive, water pipe extension division

	NUMBER OF JOBS	NUMBER OF TESTS	MILES OF PIPE TESTED	LEAKAGE MEASURED	LEAKAGE STOPPED	DISTRIBUTION OF LEAKAGE STOPPED					LEAKAGE PER MILE OF PIPE
						Joints	Broken pipe	Service pipe	Hydrant	Valves	
				<i>gallons per day</i>	<i>gallons per day</i>						<i>gals. per day</i>
Grand total for 11 years	2,539	4,211	668	8,841,328	7,948,000	1,817,550	918,325	4,201,100	909,225	101,800	13,235

the old mains were abandoned and new double main systems were installed.

In 1910 and again in 1923 all of the mains in the Union Stock Yards and Packingtown were tested and tightened. It was found that a very small percentage of the pumpage into the Yards was lost in underground street leakage. Practically all of the trouble from this source in the Stock Yards is found in mains which are beneath railroad tracks.

The 1912 Annual Report of the Department of Public Works shows that there were stopped in that year 8,456,000 gallons per day of underground leakage. During that year and previously there had been found a number of blow-off branches discharging water into

the sewers and an order to inspect and seal all blow-off branches was issued and carried out. No appropriation for water surveys was made in 1913, and all of the work of locating and stopping underground leakage was consequently stopped. In 1916 the policy of testing for underground leakage and stopping the same in streets which were to be paved was adopted by the Bureau of Engineering.

From 1916 to January 1, 1927, 668 miles of city mains were tested and 90 per cent of the underground leakage measured was located and stopped. Approximately 20 per cent of all of the water mains in the city have been covered by this survey. If the average amount of leakage per mile of pipe throughout the city is assumed to be the same as the average found on the mains tested in connection with street paving, then the underground leakage is approximately 5 per cent of the water pumped.

However, it should be considered that a great many of the streets paved were in sections where pavements had not previously been laid and where the mains had been laid in recent years. On the other hand, some very old mains, notably the 12-inch in State Street, which has been in service approximately 70 years, have been tested and found tight.

The method of testing mains for underground leakage is as follows: A section of the main about two blocks long is isolated by closing off all of the service pipes at the stopcock at the curb and by closing gate valves at the ends of the two-block section. The leakage, if any, is measured into the section through a 1- or 2-inch water meter by tapping the main and by by-passing one of the valves at the end of the section. In shutting off the valves and the stopcocks, a sounding rod and aquaphone are used on each to determine if the sound of leaking water can be detected. If leakage is indicated by the meter measurement, a number of methods are used to locate the same. The driving of rods to the main at intervals and listening with the aquaphone are used with great success. In one test recently made, 20 holes were opened and in 18 of these joint leaks were found. This was accomplished by the use of the sounding rod and aquaphone.

All of the mains in the section of the city bounded by 71st Street on the north, the City limits east and south, and Yates Avenue on the west, have been tested for underground leakage during the past year and the greater part of the underground leakage located and

stopped. The method of making these tests was similar to that used in connection with street paving work, except that instead of operating the stopcock at the curb the service was shut off at the meter by means of a wheel valve. This section of the city has many miles of mains which were laid from 40 to 50 years ago, and practically all streets are paved. In South Chicago many of these mains are at a depth of 11 to 12 feet below the present street level. They were laid in marshy ground and the street grades have been gradually raised until the water mains and service pipes are at the depth stated

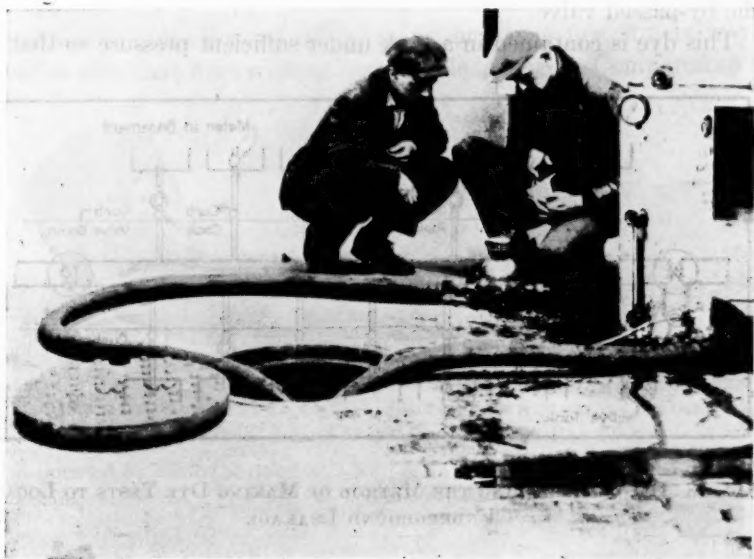


FIG. 17. DYE TANK APPARATUS USED IN CONNECTION WITH UNDERGROUND LEAKAGE SURVEYS

above and in soil which is constantly filled with water. The mains and service pipes up to the stopcock are invariably covered with water or water-bound, in which condition very little or no sound is transmitted by the leaking water. The locating of underground leaks under such conditions is almost impossible when ordinary methods are resorted to. The sounding rod and aquaphone cannot be used where no sound is transmitted as in the case of a water-bound leak.

A method of testing to determine the location of leaks where the mains are at extreme depths and where the leaks are water-bound has been developed during the last year by the engineers in charge of this work. Credit for developing the method used must be given to W. B. Weldon and L. Mauel who have been in direct charge of the field parties on this work. This method of locating underground leakage is known as the "dye method." It may be briefly described as follows: After a section of main has been isolated and the service pipes shut off, when leakage is indicated, a vegetable dye (fuchsine) which colors the water red is passed into the pipe at the location of the by-passed valve.

This dye is contained in a tank under sufficient pressure so that it

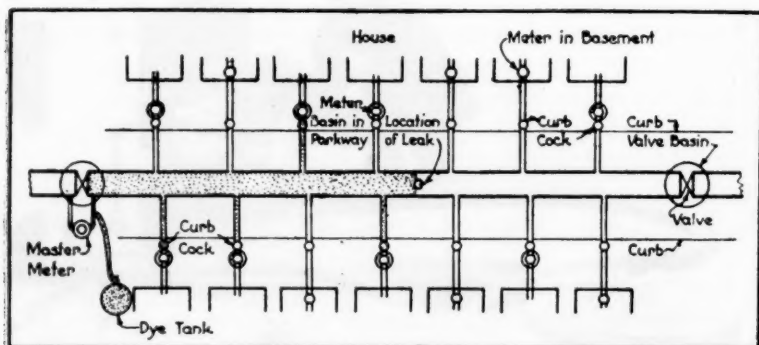


FIG. 18. DIAGRAM SHOWING THE METHOD OF MAKING DYE TESTS TO LOCATE UNDERGROUND LEAKAGE

can be forced into the main under test. The rate in feet per second at which the dye colored water in the main is moving can be determined by considering the cross section of the main and the volume of water being recorded by the master meter. After this rate has been determined the service pipe is disconnected at the first house meter and the water drawn off in a volume equal to the contents of the service pipe. If the dye has reached this point in the computed time, the water is shut off on the service pipe and the next service pipe opened and similarly tested. When a point is reached where the dye does not come through the service pipe in the time computed, it is necessary to draw off the uncolored water until the dye-colored water appears. The water thus drawn off is measured and when the

volume of the same is divided by the area of the cross section of the pipe the distance from the service pipe under test back to the point of the leak is determined. In this way the location of an underground leak can be determined without the use of sound instruments or without excavating at random. This method has been used very successfully in the South Chicago district.

About 100 miles of mains have been tested in the southeast section of the city during the past year. The total underground leakage measured in these mains is about 4,440,000 and the total stopped about 4,100,000 g.p.d.

The results of this work would indicate that the underground leakage is quite general, there being but very few streets in this entire area that were without measurable leakage. Compared to the

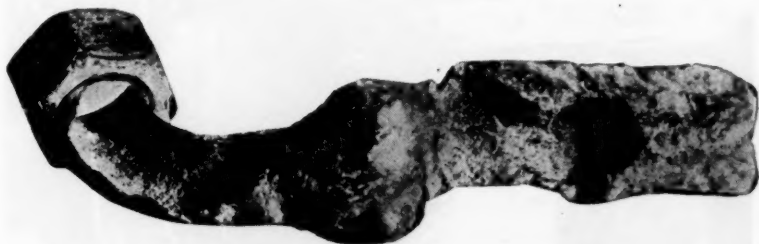


FIG. 19. MACKINAW AVENUE, 62 FEET SOUTH OF 89TH STREET; DAMAGED 1-INCH SERVICE; LEAKAGE 100,000 GALLONS PER DAY

Located by means of dye test where main had 11 feet of cover and in water bearing soil.

total pumpage into this section of the city, the water lost in underground street leaks amounted to 15 per cent.

Considering the results obtained in connection with street paving work and by the survey in the southeast section of the city, it is estimated that not less than 10 per cent of all the water pumped is lost in underground street leakage. This would amount to about 88,000,000 gallons per day.

METER TESTING AND CONTROL

It is very important where water is sold by meter measurement that the proper size and type of meter is used for each service. In Chicago the water ordinances do not provide for a service charge.

There is a minimum charge assessed, but only on buildings used for residence purposes which would pay a gross revenue of \$40.00 or less under the frontage rates.

All water used for industrial or commercial purposes is under meter control and is billed at the rate of 60 cents per thousand cubic feet subject to 15 per cent discount for prompt payment. The amount of revenue derived from industrial and commercial water service depends upon the accuracy of the meters used on services

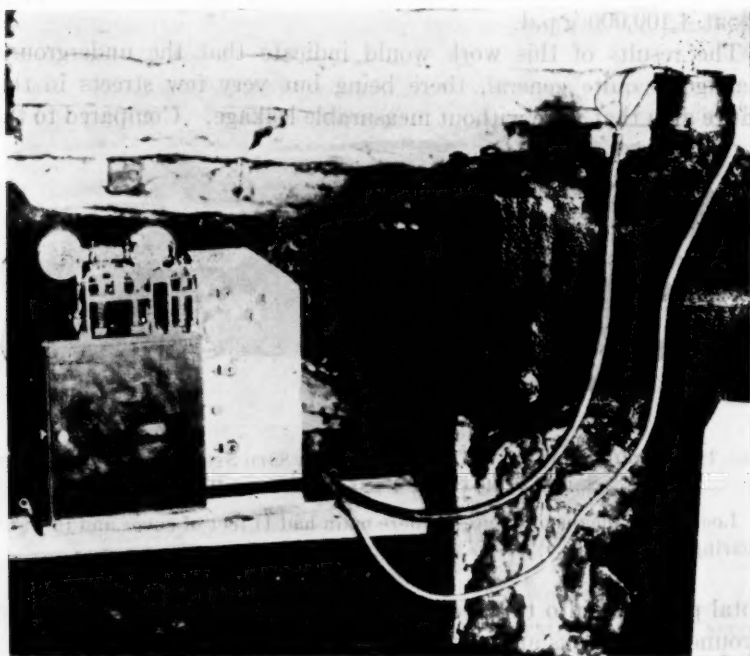


FIG. 20. RATE RECORDING INSTRUMENT ATTACHED TO 3-INCH METER, COVER-OFF

which supply water for these purposes. If a meter is too large for the service requirement, the percentage of slip will be high and the revenue derived will be less than it should be.

A method of testing meters in service has been devised and used for the past year in Chicago. Before placing an organization in the field to carry on the work of testing meters in place considerable experimentation was carried on for a period of a year and a half. One mechanical designing engineer and a helper were employed in

this experimental work. The organization, which was placed in the field July 1, 1926, consists at present of one mechanical designing engineer, three junior engineers, three rodmen and three laborers who act as helpers in the field.

A rate recorder for use in the work of testing meters has been designed by Arthur T. Seaman, a mechanical designing engineer attached to the Water Pipe Extension Division. This recorder consists of a special register which can be connected to any meter and which has connections to an electrical recording apparatus which is contained in a box 6 by 11 by 11 inches. (See fig. 20.)

The manner of connecting this recorder to a meter is very simple. The regular register is removed and the special register substituted. The wires from the special register are plugged into the recorder, a ribbon chart inserted and a clockwork started. No further attention is necessary except to keep the clock wound. A record of any desired length, from one day to a week, can be obtained.

This record is not necessarily an accurate record of the amount of water passing through the meter, but it is an accurate record of the *rate* at which the meter mechanism has recorded the passage of water. From this record a graph is plotted which shows the rate of registration in cubic feet per minute for all times while the recorder was attached. This graph is used as a guide by one who is familiar with the average accuracies of the different sizes, types and makes of water meters at various rates of flow to determine whether or not the meter in question is the proper one to record with the *greatest degree* of accuracy the water as used by the consumer.

Of course, there are other factors which may enter into the determination of the proper size and type of meter to be used, such as seasonal uses of water, fire protection needs and the use of auxiliary meters.

The results of an investigation of a 3-inch meter supplying a 16-flat 3-story building with English basement are shown herewith. This building houses about 60 persons, the water supply being entirely under city pressure. A 3-inch velocity type meter was originally set on the service pipe to this building and the upper graph shows the rate record taken from it. The amount of water recorded by this meter during a 20½-hour period, during which the rate recorder was attached, was 732 cubic feet. The maximum indicated rate of flow was about 2¼ cubic feet per minute. The 3-inch meter was replaced with a 1½-inch disc meter and another rate record taken. The 1½-

inch meter recorded for $20\frac{1}{2}$ hours 1638 cubic feet with a maximum rate of $6\frac{1}{4}$ cubic feet per minute.

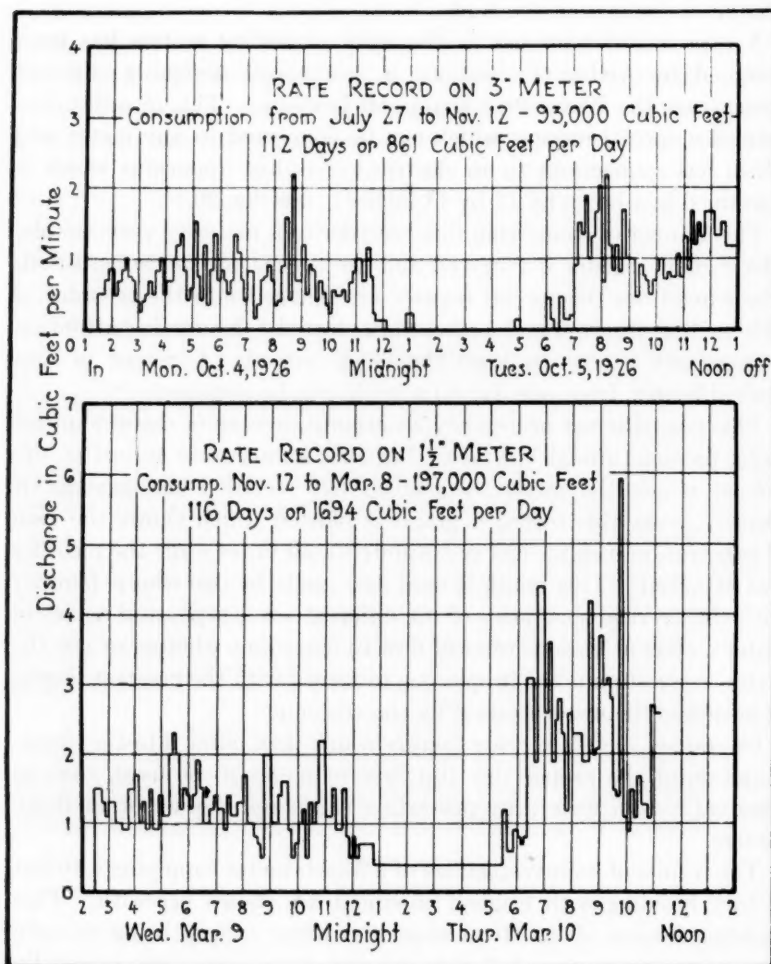


FIG. 21. RESULTS OF CHANGING FROM A 3-INCH METER TO A $1\frac{1}{2}$ -INCH METER—16 APARTMENT BUILDING

The $1\frac{1}{2}$ -inch meter recorded more than twice as much water as the 3-inch meter for the $20\frac{1}{2}$ -hour period.

The amount of water recorded by the 3-inch meter for a period of

112 days was 93,000 cubic feet, or an average rate of 861 cubic feet per day. These readings were taken for summer conditions when the use of water is at a maximum.

The $1\frac{1}{2}$ -inch meter recorded for 116 days 197,000 cubic feet or at an average rate of 1694 cubic feet per day, and this record was made through the winter months when the use of water is at a minimum. These findings are shown in figure 21.

The result of changing from a 4-inch velocity type to a 2-inch disc meter on a service pipe to an industrial plant is interesting.

A rate recorder was attached to the 4-inch velocity type meter supplying a 7-story building used for factory purposes. The maximum rates of flow occurred at 7:30 a.m. and 5:00 p.m. A number of slight movements of the meter mechanism occurred during the night hours.

A 2-inch disc meter, which is of sufficient size to supply the maximum demand, was installed. The lower graph was plotted from the rate record taken on this meter. The amount of water registered by the 2-inch is considerably higher than that recorded by the 4-inch meter. A continuous rate of $1\frac{1}{4}$ cubic feet per minute was registered by the 2-inch meter during the night hours, whereas the 4-inch meter during these hours indicated no flow.

For a period of 159 days the 2-inch meter registered 411,000 cubic feet or an average daily registration of 2584 cubic feet. During a similar period of time the 4-inch meter registered 358,000 cubic feet or an average daily rate of 2251 cubic feet. The increased registration in this instance amounted to 333 cubic feet per day.

Many buildings in Chicago have the basement and the first floor or possibly the first and second floors, supplied directly by city pressure, while all floors above the first or second are supplied by a pump through a roof tank or compression tank.

The data on a 3-inch meter on a service to a 14-story office building are instructive. The basement and first floor of this building were supplied directly from city pressure while the remaining floors were supplied from a pump through a roof tank. The pump was in operation for a total of 5 in 24 hours. During the 5 hours when the pump was in operation the 3-inch meter accurately recorded the flow while during 19 hours the rate of flow was about one cubic foot per minute which a 3-inch velocity type meter did not accurately record. A 3-inch by 1-inch compound meter was installed with the result that the rate of flow during the 19-hour period when the pump was

not in operation was increased from 0.84 to 1.11 cubic feet per minute which gave a total increase of 307 cubic feet for a 19-hour period. This would indicate that the 3-inch velocity meter was slipping about 24 per cent during the period when the pump was not in operation.

Meters have been tested in the field for about 10 months. Table 3 summarizes the tests made and the disposition or recommendation made for each test. One item in this table shows that a total of 373 three-inch meters have been tested, of which 73 were found O.K., 11 were closed and sealed, one was replaced with a 1-inch meter, 38 were

TABLE 3
Number of meters tested and recommendation made from each test

SIZE OF METER TESTED	O. K.	CLOSED AND SEALED	1 INCH	1½ INCHES	2 INCHES	3 INCHES	3 INCHES COMP.	4 INCHES	4 INCHES COMP.	6 INCHES COMP.	REC. PEND.	TOTAL
<i>inches</i>												
1½	3										3	6
2	24		4	3			2				10	43
3	73	11	1	38	168		40	1	3	1	37	373
4	88	20		4	47	5	9		16		43	232
6	68	18			3	15		6		3	24	137
8	7	1									5	13
10	14										2	16
12	2											2
	279	50	5	45	218	20	51	7	19	4	124	822

Cases requiring special installation..... 12

Requests..... 123

Total..... 957

replaced with 1½-inch meters, 168 were replaced with 2-inch meters, 40 were replaced with 3-inch by 1-inch compound meters, one was replaced with a 4-inch meter, 3 were replaced with 4-inch by 1-inch compound meters, and one was replaced with a 6-inch by 1-inch compound meter. 37 recommendations are pending. Table 3 includes recommendations made for all other sizes of meters tested.

In table 4 the saving in capital investment from 376 changes made in sizes and types of meters is shown.

Considerable time should elapse before the increase in revenue

can be accurately determined. However, an approximation of the amount of increase in revenue has been made by taking readings from 100 meters where changes have been made. These readings were taken for a period of time before and after the change of not less than 90 days. The indicated increase in annual revenue from 369 changes which have been recommended to date is \$43,000.00.

The saving in capital investment as shown above for the 376

TABLE 4

Saving in capital investment from 376 changes made in sizes and types of meter

RECOMMENDED INSTALLATION				ORIGINAL INSTALLATION	
Size	Price	Number	Value	Number	Value
<i>inches</i>					
$\frac{5}{8}$	\$7.00	1	\$7.00		
1	16.00	5	80.00		
1½	30.00	45	1,350.00		
2	42.00	223	9,366.00	9	\$378.00
3	90.00	21	1,890.00	255	22,950.00
3					
Comp.	150.00	51	7,650.00		
4	150.00	7	1,050.00	83	12,450.00
4					
Comp.	225.00	19	4,275.00		
6	300.00			29	8,700.00
6					
Comp.	450.00	4	1,800.00		
Total.....		376	\$27,468.00	376	\$44,478.00
					27,468.00
Saving in Capital Investment.....					\$17,010.00

changes in size of meters amounts to \$17,000.00. There is thus indicated a total saving of not less than \$60,000.00 for less than a year of operation of this meter control section. The cost of operating this section for 10 months has been approximately \$25,000.00.

This work is of value not only in determining the proper size and type of meter but also in the determination of the proper size of service pipes.

THE HUGHES REPORT ON THE GREAT LAKES LEVELS CONTROVERSY

BY ABEL WOLMAN¹

Somewhat over forty years ago, the City of Chicago, with a population at that time of approximately 800,000, contemplated a stupendous enterprise looking toward the protection of its public water supply and the disposal of its wastes. This enterprise included, as its primary unit, the construction of a drainage canal from Lake Michigan to the tributaries of the Illinois River. More than a decade ago the main drainage canal was completed. Uninterruptedly from that time to the present day, the engineering implications of this undertaking have been before the public of two continents, with increasing degrees of complications from an engineering, political, public health and psychological aspect.

The program of the City of Chicago, initiated in 1886, has been the subject of much legislation, long legal controversies, international discussions, detailed engineering reviews, congressional acts and United States Supreme Court decisions. The engineering program developed originally for sanitary purposes has since given rise to controversies regarding the effect of diversion of Lake Michigan water on the levels of the Great Lakes with resultant contests involving navigation and commercial interests, engineering remedies and public health necessities. Even a fairly brief review of the various negotiations and studies carried out during the past quarter of a century would consume hundreds of pages. Their importance at this time is renewed through the issuance in October, 1927, of a report of the Special Master, Charles E. Hughes, to the Supreme Court of the United States, dealing with the problems of the diversion of water from Lake Michigan by the Sanitary District of Chicago.

Inasmuch as this report involves a situation already concerning the United States and Canada, and, in the particular case at hand, the States of Wisconsin, Minnesota, Ohio, Pennsylvania, Missouri,

¹ Editor-in-Chief, Journal of the American Water Works Association; Chief Engineer, Maryland Department of Health, Baltimore, Md.

Kentucky, Tennessee, Louisiana, Mississippi, Arkansas, Michigan, New York and Illinois, there is no further necessity for justifying a review here of Mr. Hughes' findings and his recommendations to the Supreme Court. For the benefit of those readers who may care to review the antecedent events in the Great Lakes controversy, reference is made to the excellent and brief summary of the question prepared by the late John M. Goodell under the title "The Secretary of War's Concern over Water Waste at Chicago."²

REPORT OF THE SPECIAL MASTER

The Supreme Court of the United States, in an order dated June 7, 1926, appointed Charles Evan Hughes as a Special Master with directions and authority to take evidence and report thereon to the Supreme Court in the case entitled: "State of Wisconsin, et al., v. State of Illinois and Sanitary District of Chicago, State of Missouri, et al." By subsequent orders the States of New York and Michigan became additional complainants. The Special Master was to report his findings of fact, conclusions of law and recommendations for a decree, subject to examination, consideration, approval, modification or other disposal by the Court. Under date of the October Term, 1927, Mr. Hughes submitted his report.

The plaintiff States sought an injunction restraining the Sanitary District of Chicago from permanently diverting any water from Lake Michigan. If the Sanitary and Ship Canal is used as a navigable waterway of the United States, they asked that the defendants be restrained against permanently diverting any water from Lake Michigan in excess of the amount which the Court shall determine to be reasonably required for navigation, without injury to the navigable capacity of the Great Lakes and their tributaries. They further requested that the defendants be restrained from discharging wastes into the sanitary district canal in such quantity and manner as excessively to pollute the lower bodies of water.

The bills of complaint allege that the diversion at Chicago had caused a lowering of the level of the Lakes not less than 6 inches below the level that would otherwise exist; that the Sanitary District had not complied with the conditions of the permit of March 3, 1925, issued by the Secretary of War; that the acts of the defendants in

² Journal of the American Water Works Association, vol. 13, 1925, pp. 556 to 587.

the diversion of water had never been authorized by Congress and were in violation of the legal rights of the complainant States; and that the acts of the defendants were in violation of the Act of Congress of March 3, 1899 and particularly of Section 10 of that Act.

FINDINGS OF FACT

The Master reviews at considerable length and in great detail the facts established by the evidence. These facts deal with matters of geography, the construction of the Illinois and Michigan Canal, the authorization of sanitary districts in Illinois, the organization and form of the Sanitary District of Chicago, the design and construction of the Sanitary and Ship Canal and its connections, the quantity of water taken from Lake Michigan from 1900 to 1926, the development of power during the past twenty-eight years by the Sanitary District, the matters of Federal actions prior to the permit of March 3, 1925 (in this portion of the report detailed consideration is given to all of the negotiations with the State of Illinois and the Secretary of War and the various acts and grants of the National Congress), a decree in January, 1925, of the United States Supreme Court in the suit of the United States against the Sanitary District (in this case the Supreme Court enjoined the Sanitary District of Chicago from diverting or abstracting any waters from Lake Michigan over and above or in excess of 250,000 cubic feet per minute), and the permit of the Secretary of War of March 3, 1925 for permission to divert 10,000 cubic feet per second, with certain definite provisos and restrictions imposed upon the Sanitary District of Chicago.

The Report finds that, from the evidence up to the time of the taking of testimony, the Sanitary District had substantially complied with the conditions of the permit of March 3, 1925. The permit had not been revoked, although there may be some doubt at the present time as to whether the City of Chicago has complied with Condition No. 8 of the permit, namely,

"That if, within six months after the issuance of this permit, the City of Chicago does not adopt a program for metering at least 90 per cent of its water services and provide for the execution of said program at the average rate of 10 per cent per annum, this permit may be revoked without notice."

Among other things, the report reviews certain diplomatic correspondence between the Government of Canada and the Secretary of

State of the United States, regarding the diversion in question and certain modifications in the existing project on the Illinois River under the Rivers and Harbors Act of January 21, 1927. This act provides for a channel in the Illinois River with least dimensions of 9 feet in depth and 200 feet in width from the mouth to Utica.

Effect of diversion on lake levels

The comments of Mr. Hughes on the effect of the Chicago diversion on the levels of the Great Lakes is of considerable engineering interest. He reviews in detail the testimony and facts regarding this debatable question. He concludes that the full effect of a diversion of 8500 cubic feet per second of water from Lake Michigan at Chicago through the drainage canal of the Sanitary District, would be to lower the levels of Lakes Michigan and Huron approximately 6 inches at mean lake levels; the levels of Lakes Erie and Ontario approximately 5 inches at mean lake levels; and the levels of the connecting rivers, bays and harbors, so far as they have the same mean levels of the above mentioned lakes, to the same extent respectively. He supplements these findings by the statement that "An increase of the diversion at Chicago above 8500 c.f.s. would cause an additional lowering of the levels of the lakes and their connecting waterways in proportion to the amounts above stated." A total diversion of 10,000 c.f.s. would cause an additional lowering in Lakes Michigan and Huron of about one inch and in Lakes Erie and Ontario, a little less than one inch. Apparently he gives relatively little weight to the contention that some at least of the 6 inches drop in Lake levels has been brought about by other causes, in that he finds that, if the diversion at Chicago were ended, the levels of Lakes Michigan and Huron would be raised approximately 6 inches in about five years.

Damages from lake lowering

The testimony and analyses presented on both sides of the controversy, tending to show the damages to navigation and commercial interests, are reviewed at considerable length. Mr. Hughes concludes that the evidence requires the finding that the lowering of lake levels of approximately 6 inches has had a substantial and injurious effect upon the carrying capacity of vessels and had deprived navigation and commercial interests of the facilities which they would have enjoyed in commerce on the Great Lakes. The lowering, like-

wise, has been a substantial contribution to the injury in connection with fishing and hunting grounds, the availability and convenience of beaches at summer resorts and public parks. The importance of the lowering, however, in relation to agriculture and horticulture has not been sufficiently great to warrant its consideration in relation to the Chicago diversion.

Feasibility of remedial works

In a similar fashion he reviews the effect of the diversion on the Illinois and Mississippi Rivers and the feasibility of remedial works to offset the effect of the Chicago diversion. In the latter instance, he apparently accepts the report of the Joint Board of Engineers, United States and Canada, under date of November 16, 1926, as practicable. In other words, his findings indicate that the effect of the Chicago diversion may be removed by adequate engineering structures at a not unreasonable cost.

Treatment of sewage in Chicago

To the sanitary engineer the discussion of Mr. Hughes on the problem of treatment of sewage and industrial wastes, within the territory of the Sanitary District of Chicago, is of especial interest. His comments may be best summarized in his own words, as follows:

It is plain that the present flow from Lake Michigan through the drainage canal could not be immediately cut off, or reduced to 1,000 c.f.s., and in consequence the sewage of the Sanitary District in its present condition turned into Lake Michigan, without exposing the inhabitants of the District to grave risk of water-borne diseases, by contamination of the water supply taken from the Lake. The Chicago River and the waters of the Lake about the city would be filthy and noisome, with serious injury to the commerce of Chicago harbor. It appears from the testimony that it would take several years, not less than five years and perhaps ten years, or even more, before the sewage of the district, with such treatment as is practicable, could be turned into the Lake and the diversion from the Lake stopped or greatly reduced, without serious risk to the health of the people of Chicago. If the work of sewage treatment is efficiently carried on, and is extended by the most approved methods, and additional and appropriate measures are taken for water purification, it appears to be possible largely to reduce or altogether to terminate the diversion from Lake Michigan, and still to give the city of Chicago a reasonable measure of immunity from disease through pollution of its water supply. Within what time this result could be achieved cannot now be definitely determined.

To secure the utmost practicable treatment of the sewage of the Sanitary District, and to reduce as rapidly as possible the diversion of water from

Lake Michigan, without creating conditions which would seriously menace the health of Chicago, will require constant and expert administrative supervision, the continuous checking up of the results obtained by the installation of treatment works, and the insistence on such improved methods as from time to time will be available. Apart from the question of authority, which will be considered later, I find upon the facts here shown that the recommendation of the Chief of Engineers, above set forth (*supra*, p. 75) on the application for the permit of March 3, 1925, which underlay the conditions of that permit, was a reasonable one with respect to the measures immediately practicable.

The complainants have recognized the impracticability of ordering an immediate cessation of the diversion, and the suggestion made in the closing argument on their behalf before the Special Master was that the Court should determine the rights of the parties, and direct a discontinuance of the diversion, but should suspend the operation of the decree and hold it in the Court with requirements from time to time as to the action, and the time, that should be taken to bring about a condition which would permit of the decree becoming effective.

QUESTIONS OF LAW

The questions of law raised in the entire case are summarized by Mr. Hughes in the following terms:

1. Whether the complainants present a justiciable controversy and have the requisite interest to entitle them to invoke the jurisdiction of the Court; and if so,
2. Whether the State of Illinois had the right, as against the complainants, to divert the waters of Lake Michigan in the manner and for the purposes shown, without the consent of the United States; and, if not,
3. Whether Congress has the authority to control the diversion, that is, in its regulation to determine whether and to what extent the diversion should be permitted; and if so,
4. Whether Congress has given the permission; and, if it has not directly,
5. Whether the Secretary of War has authority under the Act of March 3, 1899, to regulate the diversion; and if so,
6. Whether the permit of March 3, 1925, and its conditions, are valid; and, finally,
7. As to the provisions of the decree which should be entered, in the light of the determination of these questions.

CONCLUSIONS OF LAW

Although it is possible to include here only a very brief summary of the conclusions of law in the report of the Special Master, attention of the reader is called to the very comprehensive review of laws and court decisions on the general problems of control of navigable waters, allocation of water resources, diversion of waters from one state to

another, the relative rights of individual states and of the Federal Government and the relation of questions of navigation to those of sanitation. The conclusions of law are summarized below:

1. That the complainants present a justiciable controversy.
2. That the State of Illinois and the Sanitary District of Chicago have no authority to make or continue the diversion in question without the consent of the United States.
3. That Congress has power to regulate the diversion, that is, to determine whether and to what extent it should be permitted.
4. That Congress has not directly authorized the diversion in question.
5. That Congress has conferred authority upon the Secretary of War to regulate the diversion, provided he acts in reasonable relation to the purpose of his delegated authority and not arbitrarily.
6. That the permit of March 3, 1925, is valid and effective according to its terms, the entire control of the diversion remaining with Congress.

RECOMMENDATIONS FOR DECREE

The Special Master recommended, as a result of the above findings of fact and of law, that the complainants' bill be dismissed. If a situation should develop, however, in which the defendants were seeking to create or to continue a withdrawal of water from Lake Michigan, without the sanction of Congress, or of administrative officers acting under its authority, he feels that the complainant States would be entitled to bring a bill to restrain such action. As far as future aspects of the case are concerned, the United States Supreme Court has still to act upon the recommendations of its Special Master.

If the Supreme Court acts in accordance with the Hughes recommendations, the entire controversy will probably find its place on the floors of the Congress of the United States.

LEGAL DECISIONS AFFECTING THE FINANCING OF UTILITIES¹

BY CECIL F. ELMES²

The problem of a fair basis for valuing public utilities first took anything like its present form thirty years ago in the celebrated case of *Smythe vs. Ames*, decided 1897. Utility men and their attorneys have quoted one of its most involved paragraphs ad nauseam. It is so well known that there is no need to repeat it here. Nothing is easier than to quote a court decision, or some dictum taken from it, without ascertaining the facts which furnish its background—and quite commonly nothing is more misleading. *Smythe vs. Ames* is a classic illustration of this. The historical facts underlying that lawsuit are far more significant than the language of the decree.

The suit was brought at a time when the then current market prices were at the lowest levels reached in the last hundred years. Public officials, represented by the late William Jennings Bryan, pressed for the adoption of these prices and the rejection of original or investment cost:

The ordinary business man cannot avail himself of watered stock or fictitious capitalization, nor can he protect himself from falling prices. If his property rises in value, he profits thereby; so do the owners of a railroad under similar conditions. If his property falls in value, he loses thereby; so must the owners of a railroad under similar conditions, unless it can be shown that railroad property deserves more protection than other forms of property. . . .

Much ink has been spilled discussing the language of the United States Supreme Court in deciding the suit. Most of it might have been saved by discovering the historical fact that that Court in 1897 was emerging from twenty years of controversy upon a series of fundamentals. Had the state any right whatever to fix a company's rates? If it had, was there any limit to this right? Had the judiciary the right to determine whether rates so fixed afforded reasonable compensation? Where such rates destroyed a utility's property or

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rights in property, must the destruction be total before the Court could interfere? These were a few of the questions upon which eminent jurists differed. And still more ink might have been saved by discovering that, no matter what conflicting viewpoints the verbiage of the decision implied, the Court's finding was a victory for Bryan—reproduction cost at current market prices was upheld.

In the ensuing years the United States Supreme Court's pronouncements become consistently clearer. In 1909 came the Consolidated Gas case, where the Court says:

And we concur with the Court below in holding that the value of the property is to be determined as of the time when the inquiry is made regarding the rates. If the property, which legally enters into the consideration of the question of rates, has increased in value since it was acquired, the company is entitled to the benefit of such increase.

The Minnesota Rate cases were decided in 1913, and the Court ruled:

As the Company may not be protected in its actual investment, if the value of its property be plainly less, so the making of a just return for the use of the property involves the recognition of its fair value if it be more than its cost. The property is held in private ownership and it is that property, and not the original cost of it, of which the owner may not be deprived without due process of law.

The Southwestern Bell case, decided in 1923, contains the following language:

It is impossible to ascertain what will amount to a fair return upon properties devoted to public service without giving consideration to the cost of labor, supplies, etc., at the time the investigation is made. An honest and intelligent forecast of probable future values, made upon a view of all the relevant circumstances, is essential.

In all recent cases, however, two features are significant. In the first place, price levels have changed so that now a reproduction cost valuation is higher than an original cost figure. In the second place, the public authorities who, in *Smythe vs. Ames*, urged reproduction cost at current market prices upon the courts as the only sound basis for valuation of public utilities, were now petitioning the Supreme Court to abandon the very principle they had helped to establish.

The Indianapolis Water decision, handed down by the United States Supreme Court in November, 1926, gives the latest and perhaps the clearest exposition yet available of the Court's views on

valuation of utilities. It does not modify the Court's previous findings in the least, but it amplifies them in important respects.

THE INDIANAPOLIS WATER CASE

Five of the major issues decided by the United States Supreme Court in the Indianapolis Water case are:

- (a) The basis of valuation is reproduction cost at current prices.
- (b) Going concern is a definite item which must be duly allowed for.
- (c) Water rights, where such exist, are equally a definite asset, for which the utility is to receive credit.
- (d) Depreciation is to be a subject of practical measurement, and is to be taken out of the hands of theorists.
- (e) Utilities are to earn a rate of return adequate not only to take care of their creditors, but to compensate and protect their true owners—the stockholders.

There was a mass of evidence introduced upon the subject of the original cost of the property, and the Supreme Court reviews this evidence in its finding and sets it aside. The language of Justice Brandeis, in his minority opinion, is emphatic upon this point:

Is a finding of reproduction cost tantamount to a finding of value? Is the reproduction cost which should be ascertained by the tribunal the spot reproduction cost—that is cost at prices prevailing at the time of the hearing? The District Court, as I read its opinion, answered both of these questions in the affirmative.

The United States Supreme Court, in the majority opinion, upheld the District Court.

One of the common proceedings in hundreds of past rate decisions by courts or commissions has been to ascertain a figure of so-called original cost and a figure of so-called reproduction cost—often as apart as the poles—and then to select an average figure somewhere between the two as truly representing the value of the property. The Supreme Court deals with this practice in the following language:

The decision of this Court in *Smythe vs. Ames*, 169 U. S. 466, 547, declares that to ascertain value the present as compared with the original cost of construction are, among other things, matters for consideration, but this does not mean that the original cost or the present cost, or some figure arbitrarily chosen between these two is to be taken as the measure.

As to "Going Concern," the Court confirms its previous pronouncements on this subject, that there is an element of value in an assembled

and established plant doing business and earning money over one not thus advanced, and that this element of value is a property right upon which the owner may make a fair return.

The Indiana Commission, in a previous case, had awarded the Company 9.5 per cent for "Going Value." The Supreme Court refers to the Company's fine public relations, its credit, the nature of the city and the certainty of large future growth, the way the property is planned and being extended with the future needs of the city in view, its operating efficiency and standard of maintenance—all of which had been noted by the Commission—and concludes its review of the matter as follows:

And the reported cases showing amounts generally included by commissions and courts to cover intangible elements of value indicate that ten per cent of the value of the physical elements would be low when the impressive facts reported by the Commission in this case are taken into account.

In regard to both "Going Concern Value" and "Water Rights," little need be said here except to point out that more and more the courts are emphasizing a demand for specific figures in regard to such items; a demand for an intelligent explanation of his views on the part of each witness, and a demand that rate-making bodies shall be able to specify the exact sum they allow for each of these items instead of contenting themselves with a vague assertion that the items have received such consideration as they merit.

The Court's finding on the subject of Depreciation, to many students of the art of valuation, will be even more significant than its finding on the subjects of present reproduction cost. The latter has been already pretty thoroughly established by previous decisions. The Court had before it, on the one side, a 25 per cent depreciation deduction, based on "straight-line depreciation" and the use of the now widely discredited "life tables." On the Company's side there were in evidence the results of an actual field survey by two separate groups of engineers. The Supreme Court's conclusion is clearly expressed in the following language:

The testimony of competent valuation engineers who examined the property and made estimates in respect of its condition is to be preferred to mere calculations based on averages and assumed probabilities. The deduction made in the City's estimates cannot be approved.

A careful study of this part of the Court's finding, together with the testimony presented for the Court's review, indicates that valuation

engineers will hereafter have to meet the enlightened attitude of present-day courts with a complete abandonment of certain time-honored methods of computing depreciation.

The Court's finding on the subject of Rate of Return is interesting because of the character of some of the testimony before it. The Commission had found 7 per cent to be a reasonable rate of return. The City introduced testimony as to the average rate of yield to investors on public utility bonds, some of the averages running as low as 6.11 per cent. To this the City's appraiser admitted that four-tenths of one per cent should be added to cover brokerage. In commenting upon this latter testimony the Supreme Court said:

It is obvious that rates of yield on investments in bonds, plus brokerage, are substantially less than the rate of return required to constitute just compensation for the use of properties in the public service. Bonds rarely constitute the source of all the money required to finance public utilities.

The Supreme Court's conclusion upon the Commission's finding was expressed as follows:

The evidence is more than sufficient to sustain the rate of seven per cent found by the Commission. And recent decisions support a higher rate of return.

REPRODUCTION COST AT PRESENT PRICES

The feature which at once caught the attention of utility men all over the country in the Indianapolis Water decision was the complete acceptance by a majority of the Court of present reproduction cost as the best evidence of value. Those of us who have fought for this principle through years of discouragement breathed a sigh of relief.

There are, however, earnest utility men who shake their heads at the establishment of reproduction cost as a valuation basis and look with foreboding to a future day when prices may again be at lower levels. "What will we do," they cry, "in the perhaps not far-off day when our properties can be reproduced for less than they cost to build today?"

The fact that the dollar of such a day will have a greater purchasing power, will buy more material and pay for more operating labor, and that investment capital will probably be content with a lower interest rate or yield, is not sufficient to comfort them. They seem to feel that if the courts today had ruled in favor of original cost the adver-

saries of utilities would forever be satisfied with such a finding and would hold to it, no matter how low commodity prices might hereafter drop.

As was shown in a preceding chapter, Reproduction Cost was first established as a valuation basis in just such an era of low prices. It was urged upon the court not to benefit utilities, but to hurt them; it was forced upon them by their opponents in the *Smythe vs. Ames* case. Nevertheless when the tide of price levels turned so that valuations on a reproduction cost basis got to be higher than those based on original cost, the same authorities who had helped to establish reproduction cost promptly abandoned it and became equally ardent advocates of the original cost theory.

The opponent of public utilities has been consistent, not in espousing any one theory, but in espousing whatever doctrine gave the most damaging answer from the utility viewpoint. Human nature being what it is, there is not the slightest reason to doubt that he will remain consistent in the future as he has in the past, not to any theory but to the low side, whatever it is, whether original cost or reproduction cost.

Future prices may or may not be at lower levels; prophecy upon such a topic is hazardous. Fluctuations in price levels there will always be—eras of plenty and eras of depression. No competent observer of economic history thinks of denying their existence or their almost certain recurrence in the future. But what reasons are there for looking forward to the return of a permanent level of lower prices?

A basic underlying element in the prices of today is that the wage-earner gets an adequate rate of pay. With this higher rate of pay he gives the commerce of the country the greatest stimulus it has ever had, the stimulus of great buying power in the hands of a vastly enlarged public.

FORECASTING FUTURE PRICES

Of great interest is the pronouncement of the Supreme Court in the *Indianapolis Water* case that future prices must be given consideration. As stated by one experienced observer:

. . . . the Court holds that it is not a backward look, or the averaging of past prices, which should govern, but rather, since rates are for a future period, it is proper to look to the future to determine the weight to be given to present prices.

In the Indianapolis case the Supreme Court says that "there must be an honest and intelligent forecast as to the probable price and wage levels during a reasonable period in the immediate future." There can be little question as to the soundness of this general principle, but it may be well to sound a note of caution as to its application. Who, we may ask, is to tell us the prices of tomorrow. It is a fact that appraisals have been seriously presented before courts and commissions in which engineers apparently laid claim to knowledge of what price levels will be two, three and even five years ahead, but the rest of us may be frank to admit that we do not possess this mysterious gift of prophecy.

It seems clear that the Supreme Court did not propose to put any such requirement upon engineers or commissions. It stresses the fact that it is referring to the "immediate future." If the prices of today give evidence in themselves of instability; if they occur in a cycle of rapid market fluctuations, either up or down, then the court or commission is justified in looking askance and using caution in adopting them as a basis upon which to establish future rates. It is entirely within the powers of a competent economist to advise the court or commission upon this subject.

Most people who have not had occasion to investigate the subject assume that in the years prior to the war there was a long-continued period of level and unchanging prices. Some also harbor the idea that the prices of today, while admittedly not fluctuating violently, are nevertheless much less stable than what are popularly called "pre-war prices." It will be well to correct both impressions.

There was no set dead level of prices in the generation prior to the outbreak of the World War. Thirty years have passed since the Smythe vs. Ames decision, and it is true that the purchasing power of the dollar, if taken to be 100 units in 1897, amounted to but 44 units early in 1927. It is also true, however, that the purchasing power of the same dollar was only 65 units in 1912, halfway through the thirty-year period and two years before the outbreak of the war.

Our present level of prices, while exhibiting fluctuations, nevertheless constitutes a remarkable record for general stability. For the period from May, 1922, to February, 1927, the average of the United States Bureau of Labor's Index Number of wholesale prices of commodities has averaged 153, and during that entire period of almost five years the lowest monthly index figure has been 145 and the highest 161, a maximum variation from the average figure of only 5.5 per cent.

It is reasonable to assume that the Supreme Court in calling for an "honest and intelligent forecast" of probable price levels in the immediate future, had in mind just such information rather than any vague or extravagant attempts at prophecy. It is perhaps preferable that the engineer limit himself to merely furnishing such data and leave to the rate-making body the task of applying it.

RATE OF RETURN

On the subject of Rate of Return, the decision of the United States Supreme Court in the Indianapolis Water case is especially satisfactory, not so much for the specific finding as for the language in which it is clothed. It is time that utility men laid stress upon the distinction between a public utility's owners and its creditors. It is a widespread custom in rate case testimony to lump together the bonds, stocks, notes and debentures of a utility company and to treat them as though all were very much on a parity in an investigation into the rate of return.

In the utility business the ratio of creditor securities is unusually high. This is entirely proper in view both of the stability of the enterprise and of the enormous proportion of fixed physical property to income which give utilities a wider borrowing power than manufacturing or mercantile establishments, at least as far as long-term borrowing is concerned. The creditor has unusual security as to continuity of earnings, as to the quantity of fixed physical property, and also as to its enduring character and usefulness. As a result utilities can usually issue bonds up to two-thirds of the value of their physical property, calling for interest payments equal to half their net income.

But it must not be forgotten that these bondholders are, in the last analysis, not owners of the property at all, they are only its creditors. They take a preferred position; they take little or no risk; they merely skim the cream off the enterprise, and the rate of return which is adequate for them would not be just as applied to the stockholders, who must meet every risk, every misfortune and every demand for sacrifice which the utility may make. Common stockholders of utilities run a speculative risk and should have a proportionately high reward. They have little to gain and much to lose by being lumped with bondholders, or even preferred stockholders, when courts or commissions are passing upon a rate of return for the property as a whole.

DEPRECIATION IN RATE MAKING

At the very outset of a discussion of Depreciation, a vital subject has been passed over almost unanimously by courts and commissions with far less mature consideration than the subject warrants.

If a man buys a dilapidated article, he does not commonly expect to pay as much for it as he would for the same article in condition equal to new. This being admitted, courts and commissions have almost automatically assumed that if dilapidations can be shown to exist in a public utility's property, a deduction should be made from any appraisal thereof, even though the property is not being bought or sold and the appraisal is for use only in determining future rates for service. Quite a number of these reviewing bodies have gone even further and assumed as a matter of course—and upon very scanty evidence—that such dilapidations are bound to exist.

It is not my purpose here to argue through, in any complete or connected way, the matter of why depreciation, if any, even when accurately determined, is not properly deductible in an appraisal for rate-making purposes. But it should be pointed out that here is a primary problem which has not been fully threshed out in any of the great court decisions, including those of the United States Supreme Court. It is true that there are decisions which apparently have enunciated conclusions upon the point. Examination of these cases, however, will disclose that few, if any, of them have really presented to the court, with any degree of finality or thoroughness, the complete and complex problems involved.

In what follows in this paper I have recognized the widespread prevalence of the habit of making a depreciation deduction in rate-making valuations and have discussed how the amount of any such deduction should be ascertained. It is to be clearly understood, however, that in doing so I am not in any way conceding that a deduction for depreciation is proper in appraising a public utility property in a rate-making determination. But if the rate-making body is resolved to make such a deduction and to base it upon the supposed condition of the property at the time of the inquiry, the engineer can at least show the correct way in which its true condition can be ascertained.

THE MEASURE OF DEPRECIATION

First—and worst—of all we still have with us to some extent the theorist who can depreciate your property without ever seeing it. It

is enough for him to know that in some far-off city there is a water-works whose age is 20 years, or perhaps he may have a little more detail and know that the pumping station is 15 years old, the mains, say, 25 years, and the meters 10 years old. His procedure has all the outward simplicity of a slot machine. He picks up that mysterious compilation known as a "life-table," to which I will later pay my respects. All pumping plants last 45 years, says the life-table. This one is 15 years old; it is therefore one-third dead. All water mains last 50 years, says the oracle. These are 25 years old, they must be half gone. The same authority avers that the life of a water meter is, say, 25 years. Then these must be 40 per cent used up.

The supposed depreciated condition of millions of dollars of public utility property has been determined in just this way. Figures thus prepared by men who have never bothered to inspect the property, have been gravely presented to and, in many cases, acted upon by commissions throughout the country.

There is another class of engineer whose procedure is somewhat better. This man actually inspects the property, or, more often, has his assistants do it for him. The assistant, commonly a young college boy, stands for a few seconds in front of a great unit in a pumping plant—a complex aggregation of machinery which an expert might spend days in patiently testing. There are cylinders whose internal walls he will never see. There are pistons, rings, valves, cups, dash pots, bearings—a whole shopful of parts; great castings, weighing many tons apiece; smooth, highly-machined fittings, accurate to a thousandth of an inch. The youth gazes wide-eyed at the whole complex mechanism, mutters "86 per cent condition," and passes on to the next item.

What goes on in the young man's brain that corresponds to the figure he utters? What could go on? Has he any real knowledge of the pump, its true condition, or the true condition of any portion of it? Has he some marvelous quality of second-sight to ascertain the wear upon each of hundreds of moving parts most of which are out of sight, compute the cost of their restoration, compare it with the cost of the complete machine, arrive thus at the percentage 86, and complete the entire mental operation in perhaps 5 seconds by the clock? If he has, then this country is full of mechanical and statistical geniuses surpassing anything described in the wildest fiction.

The fact is, of course, that no such mental operation goes on at all. The young man merely stands in front of the machine because he is

told to do so, and proceeds to pick a figure out of the air. If the floor of the engineroom is well swept and the equipment newly painted and shiny, he selects a figure not far from 100 per cent. If the floor is dirty and neglected and the paint on the machine a little dull, maybe somewhat dusty, then 75 per cent or thereabouts will be good enough. If bright parts of the steel-work exhibit a touch of rust he feels that 40 per cent or 50 per cent is probably about right. And if any part of the equipment is disconnected or no longer in service he will select a figure of 20 per cent or less.

Hundreds of depreciation studies of this character are handed in to courts and commissions, testified to as a field inspection of the actual condition of the property, referred to in tones of reverence and used as a basis for rulings which wipe out values into the millions of dollars.

As a serious determination of the true condition of utility property, it is a long step ahead of the man who, without leaving his swivel chair in Philadelphia, can tell you the exact physical condition of a plant in Utah or Arizona, upon which he has never laid eyes. Even so, it leaves much to be desired.

There is no reason for procedure of the character just described. A skilled man has no need of percentages, to say nothing of "life-tables" in order to determine intelligently actual physical condition in the field in the only terms in which it should ever be computed, that is, in dollars.

A competent building man can inspect any building and make up a statement of the cost of renovating it to a condition equal to new. It may need to have the brickwork pointed; it may need paint; the roof may require repair or the whole structure may need re-roofing; window sash or their frames require restoration work; plumbing, lighting or any part of the fabric may require repair or replacement. All of these items of work have their price; the field man who takes the inventory can set them forth in detail and what it will cost to do them. If he cannot he is incompetent for his job.

An able mechanical man, who has the patience to work with the plant engineer, can readily form an accurate estimate of the condition of each pump or other piece of equipment; what, if any, repairs should be effected to put it into perfect condition, and what these will cost. He can do this work while taking the general inventory of this equipment.

Other kinds of utility equipment call for different treatment.

Each class requires its own special handling. Trolley wire and steel rails are examples of equipment where there is actual abrasion and removal of the wearing surfaces. It is entirely possible to determine by calibration just how much material wastage has accrued.

Water mains and gas mains present another problem. Here what we have to measure is the extent of corrosion—internal or external or by pitting. Undoubtedly the best way to determine this is the method of taking pipe samples at selected spots over the distribution system, so arranged as to give a fair picture of the system as a whole. They are cut to standard length. Weighing or calibration, or both, will determine the extent of metal lost, if any. The depth of pits can be measured and proper allowance made for the extent of any damage they represent.

From a wide experience of cast iron mains, it is a fair conclusion that their depreciation is practically negligible. Under ordinary conditions they will last virtually forever. Where conditions are unusual, as in the case of electrolysis or factory wastes, these special conditions only extend as a rule for short distances, and the amount of pipe they affect can be ascertained very closely. From experience it can be stated that the amount so affected is commonly negligible when compared to the distribution system as a whole.

It is not possible, in the confines of this paper, to detail the practical methods to be employed in measuring the extent of physical deterioration where there is any, on all classes of property. But there is a practical method for each class, and while they vary widely, and require different kinds of men with varied experience and training, they can all be measured and expressed in dollars, and it may be said with fairness that any determination not so made is not worthy of serious consideration.

LIFE TABLES

It is about time to use plain language on the subject of life tables, because, although courts and commissions are beginning to take note of their true quality, there are still many witnesses who venture to refer to them in rate cases. It is not too much to say that every valuation decision obtained from any court or commission in which the extent of depreciation has been computed and determined upon the basis of life tables, is a decision obtained under false pretenses.

There is not the slightest doubt that many courts and commissions have been misled by the language of certain witnesses into believing

that the engineering fraternity possesses data upon the life expectancy of utility property comparable in accuracy to the data available to the engineer who computes the safe load on a bridge. Every engineer competent to speak upon the subject knows that this is not the fact, and that no one has any business to mislead a rate-making body into such a belief.

Many distinguished engineers and utility men, themselves fully aware that so-called "life-tables" are a sham and a fraud, regard the fact as so fully demonstrated as to require no further discussion. Unfortunately a scrutiny of the testimony presented in comparatively recent rate cases does not bear out this optimistic view. This testimony still teems with assurances to the courts that there are life-tables in existence which are recognized as authoritative, and that they have back of them a large body of dependable statistics and data.

For many years to come it will be necessary to stress the fact—for every competent engineer knows it to be a fact—that there is no such thing upon earth today as an authoritative "life-table" for public utility property; that the data and the wealth of statistics necessary to construct any such tabulation have never even been assembled.

THE LIFE AND ENDURANCE OF BASIC STRUCTURAL MATERIALS

It is a remarkable fact, little realized perhaps by many engineers, that, in spite of as vast accumulation of knowledge on many related subjects, we are hopelessly ignorant upon the life and endurance of nearly all the basic materials of construction.

Witnesses will undertake to advise a court or rate making body as to how long a frame or stucco or brick building should last, or copper wire or cast or wrought iron or a tile wall or roof. Yet the engineering world is practically without data today as to how long wood or copper or iron or a brick or a tile will endure. And the principal reason for our ignorance is that all these materials have an endurance and lasting quality which is enormous when compared with the span of human life.

Frame and stucco are thought of as perishable building materials, yet Ann Hathaway's cottage at Stratford-on-Avon is made of them, no better built than we commonly build now, and is in as perfect condition today as it was when Shakespeare did his courting there three and a half centuries ago.

We talk as if a brick building would do well to last a century. The writer's own boyhood was spent in an old priory, near the country home of Wolsey, the great Cardinal of the days of Henry the Eighth of England. The brick cellars of that priory were old when Wolsey was born, and Wolsey is dead 400 years and the cellars are as good today as when they were built. And even this does not remotely indicate the endurance of common brick, for across eastern Asia stretches the Great Wall of China, much of it brick, fifteen hundred miles long and two thousand years old. The copper roof of the Cathedral of Notre Dame has stood for 700 years, and is as good today as the day it was laid down and there are wrought iron floor beams in Ceylon 1200 years old, and if the iron makers of that day had furnaces to make iron equal to the product of today, history makes no record of it, and the probabilities are enormously against it.

Few people would credit a tile roof with as much as half a century of life. Yet the tile roofs of Oxford University are five hundred years old. A clay tile surely looks like a perishable product. When baked, it is easy to chip or break or crush. Yet the whole study of Assyriology comes down to us in the form of writing on clay tablets, the writing done by fine incisions as with a knife. The knife-like incisions are as clear and sharp today as if they had been done a few hours ago in wet clay or putty. Our knowledge of the very existence of vanished eras of civilization dating back 7,000 years rests on the extraordinary endurance of common pieces of tile.

It is not possible here to do justice to this fascinating story of the endurance of structural materials and the few illustrations cited will merely serve to show the extent of our ignorance upon the subject.

PRINCIPAL CAUSES OF DECAY AND WASTAGE

Our ignorance of the endurance of basic structural materials is abysmal, first, because these materials commonly have a capacity for immensely long life. Second, we have never begun a serious research into the causes of decay and wastage.

The subject is all too vast to be covered here, but merely to illustrate, I will briefly indicate the principal of these causes.

Wear and abrasion

This is the simplest and most obvious class of wastage. Trolley wire, railroad rails, the treads of stairs, platforms of railway stations, sidewalks and pavements, and public highways are all instances of

this class of mechanical deterioration all of which is capable of direct measurement.

Corrosion

Here is a vast subject, thoroughly capable of scientific analysis and treatment, which has been a subject of some of the blindest guesses on the part of so-called experts. Yet it is vital to water and gas utilities, whose most valuable property consists of iron and steel mains buried in the ground. Within the last decade there has been great advance in the electro-chemist's knowledge of the causes of corrosion. The utility man will do well to post himself on what the scientist has done.

The utility man's conclusions as to the effect of corrosion upon mains can best be reached by actually cutting out samples from the lines and determining their true condition in the laboratory. It is a simple thing to do, and has been done in a number of cases. There is no excuse today for claiming that the condition of gas or water mains cannot be determined by actual inspection.

Coincident with intelligent treatment of this important subject will come our first true understanding of the real value to the owners of the street paving commonly placed over such mains. Years ago, through sheer ignorance, we suffered court decisions to be handed down as to the value of paving over mains without anything like an adequate presentation of the facts in the case on the part of engineers. Here is a case where we not only have much to do but much to undo. Paving over mains is an important element of value, which utility men have overlooked. No one as yet has evolved standards by which to measure its worth.

Other chemical or physical changes

Crystallization in materials subjected to shock, flexure and temperature change; the hardening of rubber, the drying out of wood, leather and similar substances, with the breakdown of their fibrous structure and similar phenomena will all call for study under this head.

Effect of sunlight

Here is a field that practically no one has touched. Each individual portion of the spectrum produces its own reaction, the infra-red rays at the lower end producing heating effects, the ultra-violet rays at the other end producing actinic effects.

As to the effect of these light rays upon the life of materials, perhaps the best recent illustration is afforded by the opening of the tomb of Tutankhamen. Here are furniture, household effects and clothing left under conditions, many of which are none too advantageous to the preservation of materials, but with a total absence of sunlight. Brought out in our day their painted and lacquered and gilded surfaces are as brilliantly new and perfect as on the day the Pharaoh's body was laid with them 3000 years ago.

Discussing the present serviceability of the chairs and furniture in this and other tombs with Howard Carter, the celebrated Egyptologist, he stated that except for the consideration usually accorded to objects of antiquity, they were as usable as ordinary modern furniture.

Improper selection and use of materials

Wood sills are often used in buildings where stone or concrete should have been employed. In the oil and natural gas fields timber derricks are left unpainted and unmaintained to the mercy of the elements. In eight years perhaps they are a crumbling mass of debris. Unpainted steel pipe may be installed to handle corrosive fluids. One of the first questions to be asked when property discloses evidence of rapid deterioration is whether the materials were properly selected.

Earthquakes, floods, war and other disasters

There is no doubt that all of these causes have contributed to the destruction of great quantities of property. They are hard to anticipate or to allow for upon any basis of computation. Against some of them insurance may be obtained as a protection. Against others, humanity has not as yet devised means to protect itself. While the ravages caused by any and all of these visitations may be great, it is, however, to be remembered that they are usually local.

Fire

Here is an important cause of loss of property as to which we have statistical guidance, as well as protection in the form of insurance.

Neglect—lack of use

Here is by far the most potent agency of all, surpassing in its destructive quality all other causes of decay put together. It is the

empty house, the abandoned farm or factory that tumbles into ruin, the unrepaired automobile that falls apart. Equipment, that on the face of things looks perishable, will last indefinitely with care; equipment that should be everlasting, dies rapidly without it. There are leather belts on engines and pumps still doing service after half a century; engines that have run a hundred years; buildings in continuous occupation for centuries. But a fine engine, abandoned to rust and the elements, can become a wreck in a couple of years and a tenantless house falls apart almost visibly.

DECAY AND WASTAGE OF PUBLIC UTILITY PROPERTY

The moment we classify the causes of decay and wastage we discover that the most important of them does not apply to utility property at all.

Abrasion, crystallization, corrosion and similar phenomena react upon the property of public utilities as upon that of all humanity. But these are the minor items. If utility men today fully realized how small the total effect of all these agencies really is, they would bestir themselves to present more accurate and complete data thereon in appraisals.

Neglect and lack of use, the greatest single cause of deterioration, is ruled out. Utility properties are not neglected, they are adequately maintained, their buildings are not untenanted, their equipment is in use and looked after. Abandoned property is simply not included in appraisals made by courts or commissions today. At least half of all possible justification for a depreciation deduction disappears with this one item alone.

Fire is perhaps the next most important agency, and it again disappears bodily as a consideration in the case of utilities. Utility property subject to fire hazard is insured, and fire insurance is a properly includable item under operating expenses. The risk is real but it is provided for elsewhere and therefore has no place as an appraisal deduction.

Improper selection and use of materials is another cause of decay and wastage that is almost negligible in the case of utilities. The best and most suitable materials are almost invariably employed.

Earthquakes, floods and wars are, of course, elements of risk and possible loss to the utility company just as they are to the property of everybody but, as stated above, they are usually local and occur at long and irregular intervals. If any rate-making body, for example,

makes a depreciation deduction from the valuation of a public utility in Chicago on account of either past or future destruction through earthquake or war—it would at least be interesting to know about it.

As to true items of decay and wastage such as abrasion, crystallization and corrosion, especially the latter, it is time that engineers and utility men set themselves to the not insuperable task of actually measuring these items if only for the purpose of demonstrating to courts and commissions how small the total of their true effect really is. The next decade should see an awakening on the part of utilities to the importance of this subject and the value to themselves of properly handling it.

CONCLUSIONS

There is no such thing as finality in the regulation of public utilities, or in the development of its legal principles. These principles remain plastic and fluid, and it is well that they should. The utility business, like all others, is developing and shifting its ground from day to day. Through a long succession of legal decisions there have emerged some fairly basic features which must hereafter affect the financing of utilities. Chief among these are:

1. The courts have not in the least abandoned the wide judicial power of review of all elements of value as set forth in the old *Smythe vs. Ames* case. They can, and doubtless will, continue to hold that particular circumstances will control particular cases. But as a broad general principle, they hold definitely that present reproduction cost is the best indication of present value.

2. The courts recognize in addition to ordinary overhead or intangible items—such further elements of value as going concern value and water rights. The courts insist that the recognition of such items be in the form of specific allowances in dollars in the appraisal of the property.

3. The courts insist on an adequate rate of return and will not permit this to be limited to such an amount as will be sufficient merely to provide for the utility's creditors. The stockholder is also entitled to protection.

4. The subject of depreciation is in less satisfactory shape, but it is at least vastly better than it was. The basic propriety of deducting depreciation in a valuation for rate-making has never yet had its full day in court. Courts have assumed that a deduction must be made and have set about the intelligent determination of its amount.

5. As to the method of this determination, the courts have been eminently sane and sound. They have come to look with a critical eye upon that pernicious humbug, the so-called "life-table." They have indicated impatience with the swivel-chair theorist who deducts great sums for the supposed depreciation of property he has never seriously examined. They are willing to be greatly swayed by the practical engineer who reports the result of a methodical

inspection in the field. So far in this branch of the subject we have received all that we deserved.

6. There remains for utility men the problem of waking up to grapple with the true determination of the physical condition of their property. Regardless of whether this physical condition should be a determining factor in arriving at a rate base, it is so employed today. It is up to utility men and their engineering advisers to show by accurate and convincing measurement the smallness of any physical deterioration in ordinary utility property. We have scarcely even begun upon this work.

DISCUSSION

EDWARD W. BEMIS:³ There has been a strong drift of the U. S. Supreme Court during the last five years in favor of giving little weight to the cost of a public utility in rate cases and great weight to the cost of reproducing on present prices and also toward an allowance for going value, but this tendency has been sharply opposed by the Interstate Commerce Commission in its recent decisions and the end is not yet.

If, however, our public utilities are to get not only 2 or 3 per cent more return than a municipal plant seeks and if, in addition, they are to have their 7 or 8 per cent return computed on a rate base 50 to 100 per cent more than the cost of the property, the advantages of municipal ownership will be greatly emphasized. Municipal plants have only to earn bond interest on original cost and not even that if some of the bonds or properties have been paid for out of earnings. Few realize the momentous issues involved in the coming decisions of the Supreme Court on our railroad valuations.

Mr. Elmes has brought out very clearly that form of depreciation often referred to as physical deterioration, but does not seem to have touched upon the more important depreciation resulting from inadequacy, obsolescence and public demands such as for the removal of overhead wires and poles. He also seems to be considering only what the companies are willing to consider in a rate case as accrued depreciation while overlooking their very much larger claims for depreciation when they are trying to secure an allowance for annual depreciation in their operating expenses.

It appears to me that the only satisfactory treatment of depreciation is to treat it as the loss of service life and to apply it equally to annual and accrued depreciation, the annual depreciation being the

³ Engineer, Chicago, Ill.

annual loss and the accrued depreciation being the amount of the loss up to the time of the valuation. This is the view that has been flatly taken by the Interstate Commerce Commission in its recent orders not only to the railroads but the telephone and telegraph companies. This does not imply that Mr. Elmes is not correct in his criticism of the often ignorant and rash treatment of depreciation by public representatives. With the most careful and scientific study of the subject, however, on the part of highly experienced engineers, it remains true that depreciation is much broader than physical deterioration and that any treatment of the subject that defines depreciation one way in determining a rate base and another way in determining annual depreciation as an expense item will ultimately be rejected by all thoughtful disinterested students of the subject.

In closing, reference might be made to a far reaching decision last year of the United States Supreme Court in a New Jersey telephone case. It was there held that, if a commission allowed a company, through high charges, to accumulate more in the depreciation reserve than it was later found was the real amount of accrued depreciation, the company could keep and capitalize this excess in the reserve. The tendency of this decision, of course, will be to induce the public through its regulatory bodies to allow too little rather than too much annual depreciation in a rate case, since any excess allowance is lost forever to the public (1926 P. U. R. C page 740, decided April 12, 1926).

COST ACCOUNTING FOR WATER WORKS¹

BY PAUL M. KYDD²

I was asked to prepare a paper to be read to this convention on "The Guiding Principles of Water Works Cost Accounting." The choice of the title was most unfortunate, for I have in mind two volumes recently printed, of some 850 pages each, that cover this subject. There is one point, however, that in a brief paper of this sort may properly be emphasized; it is the simplicity of the mechanics of cost accounting.

There is no mystery about cost accounting. It is the measuring of the results of operation and the recording of the use of labor, materials and supplies, translated into the common terms of dollars, and set down in such a way as to make the results possible of interpretation. Its ultimate purpose is to show the way toward the saving of money.

I do not believe that anyone will question the need of cost data in a water works, so I will pass that by. What I would like to bring out in this paper is that while it is fine if one is able to have a cost accounting staff assembled in a bureau, the absence of such a staff does not necessarily mean that the water works must be without cost information. I shall not discuss the reason why central accounting bureaus are not always possible. What I would like to stress is that it is possible and practical to devise a cost accounting system that can be handled by the operating force of the water works with the aid of a few clerks.

In the first instance, regardless of what system is used, or where the data are assembled, the basic cost information must come from the operating section where the labor, materials or supplies are used. This information is obtained by time cards for each individual and by a statement showing the use of materials and supplies. These elements of cost can be distributed by function in each operating section by its regular force. This may sound complicated, but when you really get down to it, it is very simple. It calls for a system of forms

¹ Presented before the Central States Section meeting, September 16, 1927.

² Bureau of Governmental Research, Pittsburgh, Pa.

with explicit directions and definitions, and the insistence of the management that the records be kept. The forms should have the functions on which the management desires cost information listed on the left hand side of the sheet under the separate headings of *Operation*, *Maintenance*, *Replacements* or *Betterments*, and *Additions*. On the remainder of the sheet columns will be provided for the cost figures. The number of columns will depend entirely on how your funds are provided and how you desire to break down your cost figures. For example, if you were operating on a budget that provides your funds in separate accounts for labor, materials and supplies, you would provide a column for each of these items. You would add also a column in which to enter the work done by borrowed labor, that is labor furnished by one division to another, and one in which you would credit the function for work done by it for other sections.

The distribution of the cost items is purely mechanical and can be done by any clerk, once you work out the definitions for operation, maintenance, replacements or betterments, and additions. The definition of operation is so simple that it can cause no confusion. Determining whether an item is a maintenance or replacement charge will be troublesome, and so I suggest the following procedure. Any item of less than a given amount, say \$100 exclusive of labor, will be charged to maintenance. For all items of over \$100, employees should be instructed to telephone to some one designated person, who is qualified to apply the old yardstick of, "Does it add to the value, length of life or capacity of the plant?" Having one person making the decisions will also be helpful in keeping your valuation figures accurate, inasmuch as the decisions will tend to be uniform. The definition of additions is so simple that it can cause no confusion. The forms to which I have just been referring we will call Group 1, and on them we have entered the essential data for determining your functional cost.

Another set of forms, which we will call Group 2, is necessary for the recording of the results of operation. By setting up these forms in such a way that the items or functions correspond with those on which you have recorded the elements of cost, it is very simple to take off the results in such a way that they are readily interpreted. For example, if on Group 1 you have kept the cost of operating engines No. 1, No. 2 and No. 3, and on Group 2 you have recorded the gallons pumped by engines No. 1, No. 2 and No. 3, you can readily see that you have the cost of pumping a gallon of water by each engine.

The headings under which entries can be made on the form of Group 2 can be as detailed or as general as you desire, as long as you keep the items uniform with those on Group 1. All of the entries on both Groups 1 and 2 may easily be made by your regular employees.

So much for the cost data by function. There are places where you will require cost data by job rather than by function. This will be true particularly in the distribution section, where the major part of the work is pipe laying. In cases of this sort the procedure is identical with the distribution of cost by function, except that the forms are designed to record the distribution by job instead of by function. By giving each job a serial number it is possible by this procedure to place before the executives periodically a statement showing the total cost of each job to date, together with the amount of work done and its relationship to the total. These data can then be readily distributed by function, if this information is needed for budget purposes.

When I speak of having the cost distributed in the operating sections, the question naturally arises, do you mean all operating sections? Let me answer that in this way. The ultimate purpose of gathering cost data is the saving of money. The men who are in actual control of each operation are the ones who are in a position to save money. Therefore my suggestion is to study your organization and determine from its working just which men are in actual control of the operation, and concentrate the cost data under them. I do not mean that these men should be the only ones who should have access to the cost information. For example, if you have five pumping stations operating as a division under a supervisor of pumping stations, I would have the chief engineer of each pumping station, or a clerk under him, distribute the elements of cost for his own station. A copy of the distribution sheet would be sent from each of the five stations to the office of the pumping station superintendent, in whose office they would be summarized. The summary of the results of operation together with related cost elements would then be sent to the managing engineer of the water works. In other words, give each executive such cost information as he needs for intelligent administrative control and in such a manner that he can use it.

The proposed system has one outstanding advantage over any other system and one outstanding weakness. It may be well to mention these. The advantage in this system is that it places the cost information in the hands of those who are in position to actually affect

the saving of money, and further it has a tendency to make them conscious of the cost element of their operations, due to the fact that they themselves are responsible for compiling the figures. The weakness is that a system of this sort is dependent upon the action of so many that it is very easy through carelessness to let it break down and drift into oblivion. This weakness need not be serious if the head of the works is on his job and is a real administrator, for if he insists upon receiving complete cost reports each month, the system cannot break.

BILLING METHODS AND POLICIES¹

By J. H. KUESTER²

Billing is one of the very important phases of utilities operation, for, in order to derive any revenues which make possible the existence of a water utility, it is necessary to render bills to the customers for service rendered.

The billing department of a water utility must be efficient and accurate. Just as any successful corporation is largely governed by the efficiency and policies of its sales department, so it is with our billing department.

The billing department must necessarily be accurate to render correct bills, thereby gaining the confidence of the public. This point should at all time be foremost in our minds, especially in these days when the large private corporations are inclined to discredit the efficiency and success of municipal utilities.

A successful billing department should be courteous to its customers at all times. By taking pains to explain the reason for a large bill, which in the mind of the customer seems unjust, and by very often giving him the benefit of the doubt, we leave him satisfied and almost always convinced that we are working for his as well as our own welfare.

We bill the large consumers monthly and the smaller ones quarterly.

It is and always has been our policy to render a minimum bill in cases where the meter reader does not get a reading. We also have a set minimum charge per billing, regardless of consumption.

Until five years ago, our bills were rendered on a specially prepared bill, showing the dates of the previous and present readings, consumption, charge and rates. To these bills were attached coupons showing the consumption and charge only. These bills were sorted alphabetically and placed in pigeon-holes designated by the various letters of the alphabet. Statements of these bills were then made out, enclosed in addressed envelopes and delivered by boys to the

¹ Presented before the Wisconsin Section meeting, October 14, 1927.

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various customers. When a customer came to pay his bill, the original bill and coupon were removed from its place, the bill stamped "paid" and given to the customer, and the coupon was detached and placed in a separate compartment. These coupons were then sorted according to the order in which they appeared in the consumer's ledger, and were then entered in the treasurer's deposit record, from which his deposits are made to the bank.

The idea of boys delivering the bills did not work out very satisfactorily. Bills were often lost and perhaps not delivered. The boys grew careless and their work was subject to weather conditions and outside attractions.

Accordingly, a new bill was designed, with a coupon attached, giving the same information as the previous bill, with additional instructions printed on the coupon to enclose it with the check, if remittance was made by mail. These were printed as postal cards and sent through the mail with a one cent postage stamp attached. Under this method we were positive that the bills would be delivered, excepting those that happened to be lost in the mail. This method worked out very nicely, until the new postal regulations requiring a two-cent postage stamp on all private cards came into effect. However, when we were informed that government cards could be purchased for one cent each, we simply condensed our form and have the bills printed on government cards. In this way, we still sent out our bills for one cent. We save also the cost of the paper stock which we had to pay for under the other methods.

The methods used by our billing department are very efficient for a small utility whose gross receipts are under \$30,000 per year.

We have, as part of our billing department equipment, a hand operated addressograph and graphotype. The name, address, and page and line numbers are printed on the water bills and coupons by means of the addressograph, which saves a great deal of labor and gives the bills a more business-like appearance.

The plates for the addressograph, which contain the name, address and page and line numbers, are made on the graphotype machine. These plates are made up before each billing time, whenever new customers are added or any changes in addresses required. These plates are filed in steel cabinets, properly labeled.

Our accounts are designated by page and line numbers and the meter reader's routes are made up accordingly.

THE PRACTICAL UTILITY OF BACTERIOLOGIC CONTROL OF WATER SUPPLIES¹

BY IVAN C. HALL²

The sole significance of bacteria in water supplies relates to the transmission of the water borne diseases,—typhoid fever, the paratyphoids (alpha and beta), the dysenteries (protozoan and bacterial), and cholera. The specific causes of all of these diseases were discovered since 1880 and the accumulating epidemiological evidence that they were frequently transmitted by drinking water led immediately to the hope that their detection in water might serve as a criterion of its potability.

But this hope was soon frustrated, for the occasions upon which these organisms have been isolated directly from naturally polluted water supplies are few indeed. There are three principal reasons why the intestinal pathogens can only rarely be recovered from water supplies, (1), the relatively small number of organisms present in proportion to non-pathogenic forms, (2), their transitory persistence in water, (3), their uniform lack of distinguishing characteristics among many harmless species naturally present.

For these reasons the water sanitarian has been mainly interested in discovering criteria of pollution rather than the detection and recognition of specific causative agents of disease in water. The useful criteria are both chemical and bacteriological.

Chemical tests of water polluted with sewage show abnormal quantities of chlorides, derived from kitchen wastes, urine and feces, and a high organic content as indicated by nitrogenous compounds and a large oxygen demand. The form in which nitrogen is present is quite important; ammonia indicates recent pollution, while nitrites and nitrates indicate more remote pollution owing to partial or complete oxidation.

But the more direct criteria of fecal pollution are bacterial. This

¹ Presented before the Rocky Mountain Section meeting, February 8, 1927.

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being true, great care must be exercised in the collection of the sample. A sterilized container must be used; care must be taken by the collector not to contaminate it with his fingers; the sample secured should be representative of the supply, and should be transported to and examined in the laboratory at the earliest possible moment. I shall not take time to describe in detail the various laboratory procedures for the bacteriological examination of water. These are available to all in the Standard Methods of Water Analysis of the American Public Health Association. I shall concern myself primarily with the interpretation and practical utility of these procedures.

The biological examination of water involves both microscopical and cultural tests. The direct microscopic examination of water is of no value from a bacteriologic standpoint. But from the standpoint of algae and protozoa which may be responsible for certain undesirable flavors and odors in water it is of considerable importance. These organisms are, however, of no sanitary significance; the problems which they raise concern aesthetics, not disease.

The bacteriologic procedures are primarily cultural, and involve three phases, (1), plating for count, (2), the presumptive test, and (3), the identification of *Bact. coli* as a criterion of fecal pollution.

PRACTICAL UTILITY OF THE AGAR PLATE COUNT

It is impossible to set up any definite agar plate count as a standard of purity for drinking water. Natural water with a high organic content is likely to show a high bacterial count, yet if the organisms are not of intestinal origin, such water may be perfectly healthful. Water with low organic content is likely to have only a few bacteria and yet if these organisms are derived from the intestinal tract of a typhoid carrier the water may be very dangerous. Agar plate counts in single examinations of water specimens have little or no significance, therefore, farther than indicating indirectly whether the organic content of the water is high or low.

The practical utility of the agar plate count lies in its value as an indicator of the efficiency of purification. Treated water should have a low count, i.e., generally speaking, less than 100 colonies per cc. It is no unusual thing for modern methods of rapid sand filtration and chlorination to remove 99 per cent of the bacteria present in the water and the operation of every purification plant should be checked daily by the agar plate count as a guide to the efficiency of operation.

Another valuable field for the agar plate count is in controlling the bacterial content of swimming pools, particularly indoor pools. From an extended experience of several years in checking the bacterial content of the swimming pools at the University of California at Berkeley, I know that it is possible by chlorination with bleaching powder to keep the bacterial content of the water well within the limits commonly accepted for good drinking water.

THE PRESUMPTIVE TEST

When the early bacteriologists so often failed in their efforts to find the specific causes of water borne intestinal diseases in water supplies they directed their attention to intestinal organisms that might serve as criteria of pollution with human feces. Among those considered, particularly in England, were the streptococci, the sporulating anaerobes, and *Bact. coli*. But the first two groups have only a limited and doubtful significance, and, as the result mainly of American investigations, *Bacterium coli* is accepted all over the world as the principal criterion of fecal pollution of water.

Bact. coli has certain natural advantages as a criterion of fecal pollution. It is universally present in the intestinal tract of man. Its fermentation of lactose with acid and gas formation is a property shared with only a few organisms normally present in water, and this facilitates its detection. Its viability in water is greater than that of the intestinal pathogens, but only slightly greater, so that its presence implies at least the possibility of the co-incidental presence of the intestinal pathogens.

The presumptive test consists in the inoculation of lactose broth fermentation tubes with graded quantities of the water sample, usually 10 cc., 1 cc., and 0.1 cc.

If no gas appears in any of these fermentation tubes during 48 hours incubation at 37°C., the test is negative and the water can be regarded as certainly safe from a bacteriologic standpoint for drinking purposes. *Bact. coli* is not present and there is no evidence of fecal pollution.

If gas appears in any of the tubes during 48 hours incubation at 37°C. the presumptive test is positive. This does not necessarily mean however that the water contains *Bact. coli*, for there are at least three conditions other than the presence of *Bact. coli* that may produce gas in lactose broth, (1), anaerobic lactolytic spore formers, (2), aerobic lactolytic spore formers, and (3), symbiotic or synergic

combinations of non-gas forming lactolytic acidifiers with glucolytic gas producers. Some of the organisms are indeed of intestinal origin, but since their spores enable them to resist chemical treatment better than *Bact. coli* and the intestinal pathogens which have no spores, they are frequently present in treated water of good quality, and indicate only a remote and now harmless pollution.

Frost (1) called attention to the responsibility of the anaerobic spore bearers for false presumptive tests in 1906; they were noted again by Creel (2) in 1914, and later by Hall and Ellefson (3) (4), Levine (5), Raab (6), Meader and Bliss (7) and Sohn (8). Meader and Bliss (7) isolated 16 strains of anaerobes from 76 lactose broth fermentation tubes showing gas but no *Bact. coli*, but only two of these fermented lactose; the rest were proteolytic. They came to the conclusion therefore, that the anaerobes were unimportant factors in the fermentation of lactose in their presumptive tests.

Sporulating aerobes capable of fermenting lactose in fermentation tubes with gas formation have been recovered from water by A. Meyer (9), E. M. Meyer (10), Ewing (11) and Sohn (8).

Sears and Putnam (12) definitely showed that various combinations composed of one organism that forms acid but no gas from lactose, with another that does not ferment lactose but forms gas from glucose, may produce gas from lactose, and that symbiotic action of this sort may explain many false presumptive tests. Sohn (8), Leitch (13) and Dunham, McCrady and Jordan (14) have emphasized the same view. It seems from the observations of Castellani (15) (16) and Fiallos (17) that this phenomenon, for which Holman and Meekison (18) have recently and appropriately suggested the use of the term "bacterial synergism," is wide spread in nature. It offers an excellent explanation for the "unknown factor" in Meader and Bliss's (7) results because many of the non-lactolytic putrefactive organisms are capable of forming gas from glucose and might well serve as one of a synergic pair in the presence of acid forming lactose fermenters.

Following Churchman's (19) excellent study of the selective bacteriostatic action of gentian violet, the idea occurred to Mrs. Ellefson and myself (3) (4) that this dye might be utilized practically to reduce the number of false presumptive tests, since nearly all of the spore forming bacteria are Gram-positive. We found indeed that we could eliminate over 95 per cent of the spurious presumptive tests by this means, using 1:20,000 gentian violet in lactose broth.

It was impossible to eliminate *all* of the spurious presumptive tests because an increased amount of dye inhibited *Bact. coli* in some of the tests also. Our conclusions were confirmed by Wagner and Monfort (20), Stearn (21) and Hinman (22). The use of gentian violet in the lactose broth presumptive test greatly increased its practical value by eliminating nearly all of the positive tests due to Gram-positive organisms. When we first undertook our investigation we had in mind only the sporulating anaerobes, but it became apparent before we were through that we were also excluding sporulating aerobes, not only from the presumptive tests, but from the subcultures upon litmus lactose agar plates as well, thus facilitating the isolation of *Bact. coli* through diminution of spreaders. Even those aerobic spores that do not ferment lactose, frequently obscure the acid formation due to *Bact. coli* upon the plate by their greater production of alkali. And it seems now that gentian violet must also inhibit many false presumptive tests due to synergic production of gas where one of the synergists is Gram-positive. It is well known that the Gram-positive lactolytic (acid but non-gas forming) cocci frequently function in such synergic pairs.

In 1920, Muer and Harris (23) recommended brilliant green in lactose peptone bile, not as a presumptive but as a positive test for *Bact. coli*. Lactose peptone bile with brilliant green is superior to lactose peptone broth with brilliant green because the inhibiting dilutions for the anaerobes and for the colon group do not overlap in the former as they do in the latter. Winslow and Doloff (24) and Dunham, McCrady and Jordan (14) have shown the same thing for gentian violet; either dye can be used in a dilution of 1:1000 in lactose peptone bile without inhibiting *Bact. coli*.

Insufficient work has been done so far to determine which, if either, of these two dyes is preferable in lactose peptone bile. Howard and Thompson (25) found that brilliant green lactose bile produced fewer positive presumptives than lactose broth without brilliant green, but 96 per cent of the positives could be confirmed as due to coliform organisms, and Hale (26) recently advocated "brilliant green bile as a straight presumptive test without further confirmation."

There is a distinct need now for further comparative tests of these two dyes side by side under actual working conditions, though the results of Winslow and Doloff (24) indicate that there is little choice when they are used in bile media. But in lactose broth, brilliant

green was twenty to fifty times as toxic as gentian violet for *Bact. coli* and *Bact. aerogenes*.

In most of the literature just mentioned all coliform organisms are regarded as "*Bact. coli*." There is abundant evidence however that there are at least two main species, *Bact. coli* and *Bact. aerogenes*, each with many varieties. What little difference there is between these organisms in their resistance to the selective bacteriostatic dyes probably favors *Bact. aerogenes* and there is no likelihood at present of finding an inhibitive agent for *Bact. aerogenes* that will not act equally upon *Bact. coli*. Hale (26) holds that no significance can be attached to the difference between *Bact. aerogenes* and *Bact. coli* as criteria of fecal pollution of water. But the evidence, which has been thoroughly reviewed by Levine (5), suggests that many water supplies would be unjustly condemned if no distinction were made. Hinman (27) has recently emphasized the importance of differentiating the species. It seems certain to the writer that further procedures must be followed before a final judgment can be reached.

THE IDENTIFICATION OF BACTERIUM COLI

The next step is that of streaking out upon lactose agar plates from those tubes in the presumptive test that show gas. In these plates various acid indicators are used. Endo's medium contains basic fuchsin. Litmus is also frequently used. But both of these media have the disadvantage that the color change diffuses away from the colonies, and the most valuable medium is one that does not have this disadvantage, i.e., eosin methylene blue lactose agar, which was first adapted to water examination by Levine (28) (29).

If no acid forming colonies appear upon the lactose agar plate the water may be judged to be free from *Bact. coli* and safe for drinking purposes. The gas formation in the presumptive test was due to harmless anaerobes which would not grow aerobically upon the lactose plate.

If acid forming colonies appear upon the lactose agar plate they may or may not be *Bact. coli*. Minute acid forming colonies are usually cocci of no significance. There are a few rather rare species of hay bacilli that form gas in the presumptive test and acid upon the lactose plate; they scarcely ever grow upon Endo's medium or upon eosin methylene blue agar, and they are of no sanitary significance. Staining by Gram's method eliminates all of these from consideration. If the colonies are of moderate size and upon eosin methylene blue

medium have darkened centers they are likely to show Gram-negative non-sporulating rods. These may be *Bact. coli* but they have to be distinguished from *Bact. aerogenes*, which has little or no sanitary significance, being common in soil and natural waters. An experienced bacteriologist can readily distinguish *Bact. aerogenes* on eosin methylene blue media (but not on litmus lactose or Endo agar) by the colonial form, but final distinction rests upon the Voges—Proskauer reaction, the methyl red test, the gas ratio $\left(\frac{\text{CO}_2}{\text{H}}\right)$, and other tests.

THE SIGNIFICANCE OF BACTERIUM COLI

Supposing that *Bact. coli* has been found, what does it mean? First of all, its presence definitely implies that the water has been contaminated with feces. But there is no known method of distinguishing human *Bact. coli* from *Bact. coli* derived from cattle, horses, hogs, sparrows, or other mammals and birds (30). There is no way of distinguishing *Bact. coli* coming from a normal healthy human being from *Bact. coli* derived from a patient or carrier discharging any of the intestinal pathogens such as *B. typhosum*, *B. dysenteriae*, *Endamoeba dysenteriae*, or cholera vibrios.

It is true, as Hale (26) says, "*Bact. coli* at most means only possible fecal contamination, less possible human contamination, still less possible typhoid germs, unless the source of a supply is a river known to be contaminated by sewage."

The interpretation of a single bacteriological examination of water therefore has serious limitations. The failure to find *Bact. coli* gives the water a clean bill of health at that time. But only repeatedly negative tests can assure the continuance of safety in a supply. The placarding of a given supply as safe means nothing unless the tests are constantly repeated. It would be better to placard as unsafe the sources that are not tested and whose freedom from pollution is therefore uncertain, or those from which *Bact. coli* has actually been recovered.

If *Bact. coli* is found in a water supply, that supply is potentially dangerous, because any of the intestinal pathogens may also be present. Such water should either not be used at all for drinking purposes or used only after boiling or other effective methods of purification. If the water is to be used raw, a sanitary survey should be made, to determine, if possible, the source and nature of the pollution, and possible means for its exclusion.

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THE CORRELATION BETWEEN DIFFERENTIAL TESTS FOR COLON BACTERIA AND SANITARY QUALITY OF WATER

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Several methods have now been proposed for the differentiation of fecal from non-fecal colon bacteria. It is a matter of very great importance to determine which of these tests, when employed in testing colon bacteria from water, correlates best with the sanitary quality. In recent years, the methyl red and Voges-Proskauer tests have been used extensively as a routine laboratory practice in the bacteriological analysis of water. That these tests alone do not satisfactorily distinguish between waters of high and low sanitary quality has been shown by Cohen and Winslow (16) for some waters in the vicinity of New Haven; by Koser (8) for the waters of Washington, and by one of us Lewis (14) for some deep fissure springs which occur along the Balcones Escarpment in Texas. In all of these investigations it has been shown that a surprising uniformity prevails in the percentages of Voges-Proskauer positive organisms, whether the water is of high or low sanitary quality. There seems to be little doubt that this test has much less practical value than has generally been given to it.

In a series of investigations concerning the nutritive requirements of the coli-aerogenes group, Koser (6) has shown that differentiation may be accomplished by the use of citrates as the sole source of carbon or by uric acid as the source of nitrogen in synthetic culture media. In the citrate medium, methyl red positive colon bacteria of fecal origin fail to grow while similar forms from soil and *Aerobacter* strains from all sources are capable of utilizing the citrate and grow therein producing a marked turbidity of the medium. Koser (8) has shown, moreover, that this ability to use citrate as a source of carbon is a characteristic which is not lost or acquired by long cultivation in artificial media, or by an extended storage period in sterilized water, soil or sterilized fecal suspensions.

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Making use of the citrate test for differentiation of strains isolated from water, Koser (7) has also shown that there is much better correlation with the sanitary quality of the water than is obtained by the methyl red and Voges-Proskauer test or by the use of uric acid. He concludes that there is a group of soil colon bacteria which in other cultural characteristics are identical with the methyl red positive forms of fecal origin and indistinguishable from them except for the ability to grow in citrate media. That these soil colon bacteria should find their way into water along with the fecal type is not surprising and this has led to much confusion in the interpretation of results.

A citrate medium devised by Harder (3) for an entirely different purpose has been used by Murray and Skinner (15) for the cultivation of a variety of strains of colon bacteria. The inorganic salts used in Harder's agar are almost the same as for Koser's liquid synthetic medium. The citrate employed is ferric ammonium citrate. The medium is converted into the liquefiable solid form by the addition of 1.8 per cent of washed agar. On this medium, certain bacteria are capable of utilizing the citrate as a source of carbon, darken the medium and deposit a rusty colored precipitate of an iron compound on the surface of the colonies. Other bacteria either fail to grow or grow only feebly without depositing the iron compound or bringing about any change in the medium. Colon bacteria of the aerogenes section isolated from sewage produced turbidity in Koser's medium, darkened the Harder's agar and produced a vivid red iron rust growth. Methyl red positive colon bacteria of fecal origin failed to darken the medium or deposit iron while those of non-fecal origin were positive for both of these characteristics.

Simmons (16) has modified the original medium of Koser by the addition of agar and the indicator brom thymol blue. He obtained consistently parallel results when several hundred cultures of *Escherichia coli* and *Aerobacter aerogenes* were grown on this new citrate agar and Koser's liquid medium. He also points out certain advantages of the solid medium over the liquid. In Koser's liquid medium, it is occasionally difficult to determine whether growth has actually occurred or not. This difficulty is not encountered on the solid medium since even the most feeble growth is readily detected on the agar as minute pin point colonies. The change in color is also an advantage since *Aerobacter* colonies change the color of the agar to a

deep Prussian blue which contrasts sharply with the olive green color of the medium inoculated with *Escherichia coli* of fecal origin.

The use of cellobiose fermentation for the differentiation of colon bacteria was first suggested by Jones and Wise (5). In a series of 53 cultures isolated from feces, soil and water, they found that the strains belonging to the *Escherichia* section did not attack the cellobiose while the *Aerobacter* strains fermented it promptly with the formation of acid and gas.

In a more extensive investigation of the differentiation obtained by the use of this compound, Koser (12) has confirmed the findings of Jones in regard to the *Aerobacter* strains. In a series consisting of 241 cultures isolated from feces and soil he found that the two well marked sections of the group are readily separated by this test. *Escherichia* strains of fecal origin failed to ferment the cellobiose while *Aerobacter* strains of the same origin gave positive fermentation. Strains which were irregular when tested by the methyl red and Voges-Proskauer test, but mostly citrate positive, proved to be positive fermenters of cellobiose.

In the so-called "intermediate" type (methyl red positive, Voges-Proskauer negative, citrate positive) there was a high percentage of the cultures which fermented cellobiose. Finally some of the strains from cultivated soil, which gave the reactions typical for fecal *coli*, were about equally divided in their ability to ferment cellobiose.

The ability to produce indol has been regarded by some investigators as a valuable means of differentiating between fecal and non-fecal strains. Others have not found it of sufficient value to include in the routine methods of analysis. It is known that indol production does not correlate well with the methyl red and Voges-Proskauer reactions or with the ability to grow when uric acid is the only source of nitrogen. It may yet be shown that these differences are really in favor of rather than against the use of the indol test for the differentiation of colon bacteria isolated from water. Levine found that 91 per cent of the cultures which were of intestinal origin formed indol while only 37.3 per cent of those obtained from soil were indol positive. Many workers have recommended the test for routine practice. Levine (13) has shown by the use of statistical methods that the coliaerogenes bacteria may be divided into a small number of groups which are quite stable. The species he described were studied in relation to the source and the conclusion drawn that the recognition of species may be shown to have sanitary significance.

SOURCE OF SAMPLES AND METHODS

The present investigation was undertaken for the purpose of determining which of the above methods correlates best with the sanitary quality of the water from some deep fissure springs which occur along the Balcones Escarpment from Austin, Texas to Del Rio. This chain of springs, extending for a distance of over 250 miles, includes several of large volume located at Austin, San Marcos, New Braunfels, San Antonio, Ft. Scott and Del Rio. The geology of the region with special reference to the source of the water has been extensively studied by Hill (4) and others. The springs are in reality natural artesian wells, the water being forced to the surface through fissures in the limestone by hydrostatic pressure. The water is clear and sparkling, uniform in temperature and volume throughout the year, rather high in mineral content and slightly alkaline, about pH 7.3. The water from one of the springs is used as a source of municipal supply for the city of New Braunfels. About all of the springs extensive bathing resorts have been established, and great interest is attached to the question of the purity of the water. The water from these springs offers ideal opportunities for investigation of the types of colon bacteria in waters of high sanitary quality. There is no possible pollution at the source, as the water rushes up in large volumes from the bed rock without coming in contact with the soil.

A more detailed description of the various springs, including the geology and geography of the region together with a map of the area, and types of colon bacteria from the springs at Austin has been published by one of us, Lewis (15). For the purpose of comparison, samples from other sources have been included in this study. Some of these samples were collected from wells along the fault zone, others from earth or rock springs in the Edwards Plateau above the fault, and some from polluted surface water.

For purposes of isolation, the fermentation tube method is necessary since all of the ground waters included contain relatively small numbers of bacteria, usually less than 100 per cubic centimeter. We have used at different times plain lactose peptone broth, lactose peptone bile and lactose peptone gentian violet broth. There appears to be very little if any difference in the number of positive tubes in any of these media. Fermentation occurred more promptly in the bile medium prepared from desiccated material. All of the isolations were made at the site of the springs using field laboratory equipment.

The field work was carried out during the months of June and July, 1926. Samples were collected in sterile glass bottles and 10 cc. portions distributed at once to the fermentation tubes. An incubation temperature of 30°C. for twenty-four to forty-eight hours was employed throughout. A drop from each positive tube was streaked on eosine-methylene blue agar, Levine's formula, and the plates incubated at 30°C. for twenty-four to forty-eight hours.

Since interest in the past has centered largely around the question of the relative numbers of the *Escherichia* and *Aerobacter* sections of the group, the plates were examined and relative numbers of each type of colony recorded. In fishing colonies to agar slants, not more than one colony of each type was taken from the same plate. After isolation, the cultures were tested for purity by microscopic examination of smears stained by Gram's method. The cultures upon which the differential tests were carried out were proved to belong to the coli-aerogenes group by testing their ability to ferment lactose with formation of both acid and gas and by examination of the morphology in the Gram stained smears.

For the purpose of maintaining the cultures in a vigorous condition, we have used a slight modification of the medium proposed by Ayers (1) for work with the streptococci. This medium has been found to be of such great value that we employ it at all times for the maintenance of stock cultures. In the original formula, 7.5 grams of agar are required per liter of the finished medium. We have reduced this amount to 5 grams in order to change the consistency to that of a semi-solid medium for use in determining motility. In this modified culture medium, the various members of the group grow luxuriantly and motility is shown in a most striking manner. Cultures in which the cotton stoppers have been sealed with paraffin and stored at low temperature remain viable and vigorous for long periods of time. We have kept our entire collection of cultures as long as six months before transplanting to fresh media.

A total of 320 cultures isolated from 53 sources have been studied. Differentiation has been accomplished by means of the Voges-Proskauer and methyl red tests, growth on citrate media of various formulae, by means of cellobiose fermentation and the production of indol. The cultures were grown in Clark and Lubs medium at a temperature of 30°C. for five days and then tested for final hydrogen ion concentration by means of methyl red indicator and for acetyl-methyl-carbinol, using the technique proposed by Chen and Rettger (2). In all cases in which the reactions were not clear cut, they were recorded as irregular.

The liquid synthetic sodium citrate medium was prepared in accordance with Koser's original formula. Cultures were made in this medium by transferring from water suspensions prepared by emulsifying a loopful of bacteria from an agar slant in a few cubic centimeters of sterile water. These cultures were incubated at 37°C. for forty-eight hours and examined for presence or absence of growth. Cultures in which turbidity was not clearly established at this time were held at room temperature until the end of the fifth day for the final reading.

The sodium citrate agar proposed by Simmons was prepared by adding 2 per cent of agar and 1 per cent of a 1.5 per cent alcoholic solution of brom thymol blue to the liquid medium. This agar was sterilized at 15 pounds pressure and poured into sterile petri plates. The agar was inoculated by streaking a loopful of a water suspension on the surface. The cultures were incubated at 37°C. for forty-eight hours and results recorded or incubation continued at room temperature in case of doubtful reactions.

Harder's synthetic ferric ammonium citrate medium made up in the same proportions as that used by Murray and Skinner (15) was solidified by the addition of 2 per cent of agar. This was inoculated and incubated in the same manner as the sodium citrate indicator agar. The agar used in both of these media was thoroughly washed with distilled water and the media were prepared from freshly distilled water.

The cellobiose used in these experiments was a Phansteil product procured from the Special Chemicals Company. Since this substance is very expensive it was used in as sparing a manner as possible. The method employed by Koser (12) proved entirely satisfactory and enabled us to test the entire collection of cultures with a small amount of the material. In addition to the above differential media the cultures were grown in tryptophane broth for the indol test, in sucrose, salicin, dulcitol and wherever these tests indicated the necessity of further differentiation, in gelatin, glycerin and starch. Fermentation tubes containing extract indicator broth plus 0.5 per cent of the fermentable substance were employed. Motility was recorded from 24 hour cultures grown in the semi-solid Ayers medium. In cases where any doubt existed the results were checked by microscopic examination of twenty-four-broth cultures. Tests for indol were made by Ehrlich's method using 24 hour cultures grown in tryptophane broth.

In addition to the standard routine methods of cultivation and differentiation we have attempted to devise some improvements in citrate media. In the use of synthetic media containing citrates or other simple organic compounds the test, as applied in the past, has depended on the ability of the organism to utilize a single source of carbon for growth. To determine whether or not growth has occurred it has been necessary to rely on turbidity tests or as in the case of the modified indicator agar on the development of colonies and change of reaction in the medium.

That a test depending on ability to utilize a single source of carbon

may be influenced by impurities in the agar, the distilled water, or in the inorganic chemicals used seems not unlikely. Our experience has been that many strains of colon bacteria develop slowly in all of the simple synthetic media and that the final result is at times very difficult to determine accurately. We have sought to obviate these difficulties by the use of a citrate medium containing all the organic substances necessary to promote abundant and vigorous growth and at the same time supply the citrate in such a form that when utilized a brilliant visible reaction occurs.

For this purpose ferric ammonium citrate is an entirely satisfactory compound. Organisms capable of utilizing this salt, when no other source of carbon is available, attack it promptly and with equal vigor in the presence of additional nutritive substances. The reaction is manifested by a darkening of the medium and by the deposition of the rusty deposit of iron on the surface of the colonies. Our experiments have shown that several factors influence the deposition of the iron compound. In some of the formulae tested the reaction is delayed or almost entirely suppressed while in others it occurs promptly.

In order to test the organic nutrients which may be used as well as the influence of certain inorganic salts, three groups of cultures were selected based on their growth on synthetic citrate media. One of these groups produced turbidity promptly in the liquid medium, and developed colonies with the characteristic reaction in both Harder's and Simmons' agars within twenty-four hours. The second group grew slowly on all synthetic media with delayed reactions and the third was negative.

Several formulae have been tested and the fact established that the slow growing forms with delayed reaction may be so influenced by the nutritive medium as to react as promptly as the forms which grow more vigorously on the simple synthetic media. In no case have we been able, however, to stimulate deposition of the iron compound by a strain in the colon group which fails to grow in Koser's medium or Harder's synthetic agar. Other iron depositing bacteria have not been tested.

The deposition of iron hydroxide appears to be influenced by the kind of peptone, the presence of meat extract, the amount of ferric ammonium citrate and by the inorganic salts used. Murray and Skinner (15) tested the effect of substituting ferric ammonium citrate for the sodium citrate in Koser's medium but found that the reaction

was less pronounced when this formula was used. Harder (3) found that several unclassified organisms deposited the iron compound from ferric ammonium citrate when the salt was added to Heyden's nahrstoff agar. According to his report this reaction took place rather slowly. He also tried the use of various infusions and of soil extract but without success.

On a nutritive agar containing 1 per cent of Bacto peptone, 0.35 per cent meat extract, 0.5 per cent sodium chloride, 0.8 per cent ferric ammonium citrate, and 2 per cent agar, with a reaction of pH 7.2, the strongly positive strains produced the iron deposit within a few hours, the slow positives after forty-eight to seventy-two hours, while the negative strains failed completely to deposit the compound after prolonged incubation. The entire collection was grown on agar of this formula. The differentiation was identical with that obtained on the synthetic media. On a nutrient agar of precisely the same formula, but with the addition of 0.3 per cent of monobasic potassium phosphate, the reaction was delayed and feeble in all strains. Similarly on a rich culture medium made from beef infusion, with the addition of peptone, glucose and potassium phosphate the reaction was almost completely inhibited. Heyden's nahrstoff agar was found to give a very slow reaction.

In a 1 per cent peptone agar containing 0.8 per cent citrate the deposition of the iron compound took place more readily with the addition of 0.5 per cent sodium chloride. Three brands of peptone were tested, namely, Bacto, Witte's and Bacto proteose. In both Witte's and proteose peptone there is a slight tendency for the citrate to precipitate during sterilization unless the reaction is adjusted to the alkaline side of neutrality. This difficulty was not encountered with the Bacto peptone. Witte's peptone proved to be the least satisfactory of the brands tested. The reaction was slow and weak even for the strongly positive strains and completely inhibited in the slow positives. Either Bacto or proteose peptone may be used. The deposition of iron takes place more promptly with the proteose brand and we have not found it necessary to adjust the reaction.

The results obtained from 1 per cent meat extract agar without peptone showed that the citrate is used promptly by both the strong and slow positives. The addition of sodium chloride seemed to stimulate slightly.

No attempt has been made to exhaust this phase of the subject. Doubtless a more critical study of all the factors influencing the

deposition of the iron from ferric ammonium citrate would yield interesting results. Our purpose has been to obtain a formula which would give a sufficiently sharp reaction to make the reading of results possible with accuracy within twenty-four to forty-eight hours. For this purpose any of the formulae described above as satisfactory may be used.

RESULTS OF THE DIFFERENTIAL TESTS

The cultures may be divided into two groups on the basis of the sanitary quality of the water from which they come. All surface waters as well as springs and wells in close proximity to houses, barns or in pastured areas were included among the polluted sources, while the deep fissure springs, earth and rock springs and wells which were

TABLE 1
Results of differential tests

	POLLUTED WATER		HIGH SANITARY QUALITY WATER	
	Num-ber	Per cent	Num-ber	Per cent
Methyl red acid and Voges-Proskauer negative....	72	86.7	185	78
Methyl red alkaline and Voges-Proskauer positive..	10	12	43	17.7
Methyl red alkaline and Voges-Proskauer negative..	1	1.2	9	4.1
Citrate negative.....	61	73.5	81	34.1
Cellobiose negative.....	56	67.4	72	30.4
Indol positive.....	56	67.4	101	42
Cellobiose acid positive and gas negative.....	0		21	8.9

removed from obvious sources of pollution were classed as unpolluted supplies. On this basis 83 cultures were derived from polluted water, while 237 came from supplies where pollution was not evident from an examination of the immediate source. Table 1 shows the results for all of the tests used. The results show a very high degree of correlation between the methyl red and acetyl methyl carbinol tests in the polluted samples. A single culture was negative in both of these tests. In the waters of high sanitary quality, the correlation is less perfect, as there were 10 cultures which were acid to methyl red, but failed to produce acetyl methyl carbinol or were so irregular in this respect as to render the results doubtful. The majority of these cultures were isolated from a single earth spring. That they belong to the *Aerobacter* section there seems little doubt when the

colonies are examined on agar or when the cellobiose fermentation is considered.

When the polluted samples alone are considered the methyl red and Voges-Proskauer tests would seem to correlate better with the expected results than the citrate test. It is shown that some of the methyl red positive forms occurring in these sources are able to utilize citrates. That these forms were derived from the non-fecal soil flora seems not unlikely. It is in the waters of better sanitary quality that the citrate tests show a striking superiority. Here it is seen that the emthyl red and Voges-Proskauer tests fail to distinguish sharply between the two classes of water. The percentages are slightly in favor of the higher quality water but not markedly so. When the citrate test is considered it is seen that the correlation with the source is more clearly marked. The waters of high sanitary quality, taken

TABLE 2
The correlation between methyl red, indol and citrate reactions

	POLLUTED WATERS		UNPOLLUTED WATERS	
	Citrate +	Citrate -	Citrate +	Citrate -
M.R. + Indol +	3 (5.3%)	53 (94.6%)	27 (27.8%)	70 (72.1%)
M.R. + Indol -	9 (56.2%)	7 (43.7%)	81 (92.1%)	7 (8.0%)
M.R. - Indol +	0	0	4 (75.0%)	1 (25.0%)
M.R. - Indol -	10 (90.9%)	1 (9.1%)	4 (95.8%)	2 (4.2%)

as a whole, show 78 per cent of fecal strains when classed according to the methyl red and Voges-Proskauer reactions, but only 34.1 per cent on the basis of their ability to use citrates.

The test for indol production is less conclusive. Correlation in a general way is shown in the two groups. The percentage of indol positive strains is greater in the cultures from polluted water but the difference is less marked than that brought out by the citrate test.

The indol test has been quite generally abandoned because of its failure to correlate with others especially the methyl red and Voges-Proskauer reactions and because the reaction was thought to be inconstant. We have included this test for the purpose of determining whether or not there is a correlation between the ability to utilize citrates and the production of indol. The results are shown in table 2. Here it is seen that the methyl red indol reactions divide the organisms into three well marked groups. The first of these, the

methyl red positive, indol positive contains 56 cultures from the polluted waters and 97 from the waters of high sanitary quality. These same cultures when grouped according to ability to use citrates are found to be principally citrate negative, being 95 per cent negative for the polluted water and 72.1 per cent for the water of better sanitary quality. The second group which is acid to methyl red and negative for indol production consists of 16 cultures from the polluted and 88 cultures from unpolluted sources. These are principally citrate positive, 90.9 per cent in the better class of waters, while in the polluted waters the percentages are about equal, being 43.7 per cent for the former and 56.2 per cent for the latter. The methyl red negative, indol negative group contains 59 cultures of which 56 are citrate positive, and three are negative. These results seem to show that all of the methyl red positive organisms which occur in waters either of high or low sanitary quality should not be classed as of fecal origin. If the citrate test is to be considered a reliable means of differentiation, then it would appear from our results that the differentiation obtained in the past in which the indol test was used are more reliable than those obtained by use of the methyl red and Voges-Proskauer tests alone. We believe that further investigations along the line of citrate and indol correlation are desirable.

The results of the cellobiose fermentation confirm the findings of Jones and Wise (5) and of Koser (12), for the *Aerobacter* section since all of these strains were positive. The strains which gave a variable or indefinite reaction for acetyl methyl carbinol proved to be principally cellobiose positive. From a total of 10 such strains 8 proved to be positive for acid and gas while 2 produced acid only. In the *coli* section, fermentation of cellobiose is variable. Of the 72 strains of methyl red positive, Voges-Proskauer negative organisms isolated from waters of low sanitary quality, 16 proved to be capable of fermenting the compound with formation of acid and gas. These cultures were found to be principally citrate positive. In the case of similar cultures isolated from waters of high sanitary quality 92 were positive, 72 negative and 21 produced acid but no gas. Again there is a very close agreement between cellobiose fermentation and the ability to use citrates. The results of these tests are shown in table 3.

The question concerning the sanitary significance of definitely determined species has not been extensively studied. Levine (14) found in a series of 333 strains isolated from soil and feces of various animals and man that certain species were found only in soil, others

only in feces, while some were isolated from both sources. As a result of this he suggests the desirability of further work along the line of species determination in relation to sanitary quality of water. The matter concerning taxonomic characteristics which should be used in the classification of this group has been most troublesome and there seems to be even now a lack of uniform opinion. For our present purpose, we believe the scheme proposed by Levine, based on a statistical study of the group, suffices as well as any that has been used.

In the 72 methyl red positive Voges-Proskauer negative strains isolated from polluted water we have identified as *E. communior* 31 (43 per cent), *E. neopolitanum* 1 (1.4 per cent), *E. coscoroba* 4 (5.6 per cent), *E. coli* (motile) 6 (8.3 per cent), *E. coli* (non-motile) 1 (1.4 per cent), *E. acidi lactici* 23 (32 per

TABLE 3
Distribution of species and reactions in the coli section

	POLLUTED WATER						HIGH SANITARY WATER							
	Citrate +	Citrate -	Indol +	Indol -	Cellose +	Cellose -	Citrate +	Citrate -	Indol +	Indol -	Cellose +	Cellose -	Cellose A + G -	
E. communior.....	7	24	26	5	5	26	55	19	32	42	39	20	15	
E. neopolitanum.....	1	0	0	1	1	0	0	0	0	0	0	0	0	
E. coscoroba.....	3	1	1	3	3	1	15	0	10	5	15	0	0	
E. coli.....	0	6	6	0	2	4	7	14	14	7	8	12	1	
E. coli (immobili).....	0	1	0	1	0	1	0	1	1	0	0	1	0	
E. acidi lactici.....	1	22	20	3	5	18	31	30	30	31	27	29	5	
E. acidi lactici (immobili).....	0	6	3	3	0	6	1	12	9	4	3	10	0	

cent), *E. acidi lactici* (immobili) 6 (8.3 per cent). In 185 similar strains from waters of better sanitary quality, there were *E. communior* 74 (40 per cent), *E. neopolitanum* 15 (8.1 per cent), *E. coscoroba* none, *E. coli* (motile) 21 (11.3 per cent), *E. coli* (non-motile) 1 (0.5 per cent), *E. acidi lactici* (motile) 61 (33 per cent), *E. acidi lactici* (non-motile) 13 (7 per cent).

It is obvious that the distribution of these groups does not distinguish between the two classes of water since the percentages are almost identical. The only point which might be considered to have any sanitary value is the small number of *E. coli* strains. It is well known that *E. communior* and *E. acidi lactici* are more prevalent in

soil and in animal feces while *E. coli* is the dominant strain in humans. We have considered also the relation of species to indol production, ability to utilize citrate and the fermentation of cellobiose. The results are shown in table 3.

DISCUSSION OF RESULTS

The results obtained show that the organisms isolated from the polluted waters and from the waters of better sanitary quality belong principally to the *coli* section of the group. This might be interpreted in either of two ways. Either the sanitary rating given to the waters of high quality is in error or the method of grading water according to the methyl red and Voges-Proskauer reaction does not correlate with the sanitary quality of the water. We are aware of the fact that in a sanitary survey it is impossible to determine pollution with precise accuracy. If this could be done then the bacteriological analysis would have no significance. It is also true that the differentiation by citrate media shows a somewhat higher percentage of negative strains than would appear to be probable in waters of the highest sanitary quality. We believe, however, that the sanitary survey of the sources has been done with as much care as is possible under ordinary conditions. It is scarcely to be expected that the sanitary survey and the results of bacteriological analyses would coincide completely in such a group of sources as has been included in this investigation. Some of the sources rated high in sanitary quality have given a higher percentage of citrate negative strains than others. In general, it is true that the earth and rock springs from the Edwards Plateau gave fewer such strains than the waters from wells and springs located along the fault zone. This is a limestone formation characterized by numerous faults, as well as horizontal and vertical cracks and fissures. The precise origin of the water which gushes up from a considerable depth through these fissures is not known. That it comes mostly from a considerable distance is almost certain. It is in such waters as these that the bacteriological methods are of greatest value. A test which correlates with waters of known pollution and with others of the highest sanitary quality may be considered reliable when applied to cases which are of necessity doubtful. The ability to utilize citrates, and the fermentation of cellobiose have each been shown to divide the methyl red positive strains into two groups one of which predominates in the polluted waters and the other in waters of better quality.

Either of these methods of differentiation might be used. However, the high cost and lack of availability of cellobiose eliminates it for practical routine purposes.

The citrate test is more easily and quickly applied than the methyl red and Voges-Proskauer reactions and has been shown to correlate better with the sanitary quality of the water. We prefer to use the ferric ammonium salt added to a nutrient agar base. Such a medium is easily prepared, it is stable and may be inoculated in the same manner as any nutrient agar. The reaction occurs promptly and is so striking that errors in reading results are improbable. It is to be preferred to the indicator agar proposed by Simmons, since several cultures may be tested on a single plate without the results being obscured by the diffusion of color. For the routine analysis of water we believe that data of sufficient accuracy may be obtained by confirmation of the fermentation tubes on eosine-methylene blue agar and subsequent transfer of several colonies from each of the positive plates to ferric ammonium citrate agar.

SUMMARY

1. Colon bacteria isolated from waters of different sanitary quality have been tested by means of the methyl red and Voges-Proskauer reactions, indol production, ability to use sodium and ferric ammonium citrates and by the fermentation of cellobiose.

2. The citrate tests have been made in liquid synthetic sodium citrate media; in the same medium plus agar and brom thymol blue; and in ferric ammonium citrate agar of various formulae.

3. Agar containing 0.8 per cent ferric ammonium citrate and 1 per cent of either proteose peptone or meat extract gives a more prompt deposition of ferric hydroxide than is obtained on synthetic agar.

4. The citrate test gives a better correlation with the sanitary quality of the water than the methyl red and Voges-Proskauer reactions.

5. Indol production and the methyl red reaction combined correlate better with the sanitary quality of the water than the methyl red and Voges-Proskauer tests alone.

6. Species of the methyl red positive group may be either positive or negative as to ability to utilize citrates.

7. Cellobiose fermentation occurs in all Voges-Proskauer positive strains. The coli section contains some strains which ferment cellobiose and others which do not. The cellobiose negative strains are principally citrate negative.

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THE MICROSCOPY OF DRINKING WATER¹

BY GEORGE CHANDLER WHIPPLE; REVISED BY GORDON M. FAIR
AND MELVILLE C. WHIPPLE

A REVIEW BY W. C. PURDY²

The growing interest and importance of water problems in which microscopic organisms constitute a little-known factor insure a cordial welcome to any text designed to shed light on these matters. It is of general interest, therefore, that the monumental work of Professor George C. Whipple, of honored memory, has been thoroughly revised, and much new material has been added, this fourth edition containing almost twice the number of pages the first edition contained, published twenty-six years ago.

The first of the two main sections of the book deals with Applied Microscopy, the second section with Determinative Microscopy, describing, classifying and illustrating the various organisms commonly found.

The first section discusses the Why and the How of microscopic examinations, describes and illustrates new methods and apparatus, and records the apparent significance of certain findings as indicated by the observation and study of various investigators.

Several of the major biological problems of water supply are discussed in detail, and methods of solution or mitigation are suggested. These suggestions are based on modern successful experience, and on results obtained by various research workers. After a study of such chapters as Odors and Tastes in Drinking Water, Control of Algae, and Microscopic Organisms in Water Conduits, one feels that, though there is much to learn, one is no longer groping in the dark when encountering these common but serious situations.

A wholesome restraining tone is evident throughout the book. This is seen in the guarded statements, in the evident effort to give fair appraisal to all known factors, and in occasional warnings against

¹ A Fourth Edition, published by John Wiley and Sons, Inc., New York and London, 1927. 586 pp.

² United States Public Health Service, Cincinnati, Ohio.

impractical methods and unwarranted conclusions. For example, the injunction on page 48 that "interpretation of results be clearly presented, without misleading statements and without false conclusions" . . . is entirely compatible with the straight thinking of the true engineer or sanitarian.

Those familiar with the earlier editions of this work will welcome a large amount of valuable new material in the present issue. A chapter on Microscopic Organisms and Sanitary Water Analysis emphasizes the advisability of considering the evidence obtained from microscopic examinations, together with the interrelated and better-known evidence obtained from bacteriological and chemical data meantime. Something of the probable significance of certain bottom organisms is set forth, together with much additional material relative to the rôle of aquatic life in general, in a timely chapter on Self-Purification of Streams. Special mention should be made of Ecological Classification of Microscopic Organisms, inasmuch as this chapter is perhaps the first considerable attempt appearing in an American text to classify the more common microscopic organisms with reference to their preferred environments, particularly as to the presence of polluting matter such as sewage. The observations of various workers both here and abroad are recorded, with the result that the microscopic organisms predominating in a given water may now be associated with the probable sanitary significance attached thereto. While this classification is to some extent tentative and necessarily incomplete, yet it is real progress in the right direction.

Mechanically the book leaves little to be desired. Type, paper, illustrations and graphs are of excellent quality. Each chapter closes with a bibliography. Glossary and index are appended. Nineteen pages of plates, most of them colored, illustrate the more common types of aquatic organisms. These plates, while excellent as to form, are in several instances not entirely satisfactory as to the attempted natural color.

The essence of the book is that microscopic organisms are not only present, in greater or less abundance, in every natural water, but that frequently *their presence means something* in terms of the sanitary status of the water. Just what this meaning is, and the interpretation that the sanitary engineer may safely place upon these biological findings, is discussed and illustrated with a thoroughness that will, we believe, commend this 1927 edition to engineers, biologists, and sanitarians in general.

BOILER FEED WATER PURIFICATION¹

BY SHEPPARD T. POWELL

A REVIEW BY HAROLD FARMER²

The task of the chemist whose duty it is to purify water for boiler purposes has never been a light one and in recent years this burden has increased due to changes in methods of operation and increasing pressures and temperatures. A realization of the fact that the softening or purifying of water does not terminate at the feed pumps, but must be under control until purified steam is delivered to the prime movers also increases the water chemist's burden.

Many investigators have specialized on the correct treatment of feed water for boiler purposes and their findings have been published in technical journals, but nowhere has there been any attempt to correlate this information and place at our disposal a treatise on the entire subject.

In Mr. Powell's book "Boiler Feed Water Purification" the author has carefully analyzed the various methods and apparatus for purifying water and has presented the advantages and disadvantages of the various processes so that the selection of the purifying apparatus can be intelligently made. Combined with this is a study of the economics involved, so that, other things being equal, the cost of operating can also be considered in the selection.

The first chapter in this book explains the origin of impurities found in water; the properties of the various impurities and effects when used for boiler purposes.

The following chapters which have been carefully arranged and classified show the value and types of preliminary settling basins; the purpose and method of chemical coagulation for removing fine material in suspension, and factors influencing coagulation.

The theory of filtration is described and the operation and relative merits and demerits of pressure and gravity filters are considered.

¹ Published by McGraw-Hill Book Company, New York and London. 1927. 363 pp.

² The Philadelphia Electric Company, Philadelphia, Pa.

The chemistry of water softening by chemicals is described and the operation of intermittent softeners and continuous softeners. Relative merits and cost of treatment are presented as well as the relative merits of hot and cold softeners.

Softening water by zeolites; the advantages and disadvantages; the important factors to be considered when comparing against other forms of softening are set forth.

The theory of evaporators is enunciated; domestic and foreign types are described and a thorough discussion of results of purifying by this method is presented. Some very important facts are brought out which heretofore have not been generally known.

Another chapter has been devoted to the Deaeration of Feed Water and the methods employed for complete degasification. The necessity for complete degasification is emphasized, particularly when this form of apparatus is used in conjunction with evaporators in connection with boilers operating at high pressures.

The value of Deconcentrators and Continuous Blow-down systems is shown.

The treatment with Boiler Compounds is presented in its true form and the undesirability of this form of treatment shown.

The chapter describing some of the causes of Priming and Foaming is very thorough and comprises the most recent information obtained by prominent investigators. In another chapter on Corrosion the author shows the various factors which influence the rate of corrosion in steam boilers and preventative measures for combating corrosion.

A chapter has been devoted to Embrittlement of Boiler Metals. The author has presented a condensed review of the significant points brought out by many investigators of this much discussed subject and has presented in an unbiased manner the findings of the investigators which recently have been very conflicting. While no authority can state definitely the cause of boiler steel embrittlement, a study of this chapter cannot but impress the reader with the importance of this subject and the necessity for continued investigation.

A chapter on feed water heaters and miscellaneous treatment follows.

The final chapter covers the standard methods of water analysis which are presented for the control of feed water treatment. These methods are very complete and the significance of the tests is described.

The book contains a valuable bibliography at the end of each chapter.

In preparing this book the author has combined with his own knowledge and vast experience, the findings of other investigators and presents the entire subject of boiler feed water purification in such a manner that it is comprehensive to those who are not so familiar with the subject.

The book is of special interest to those operating boilers at high pressures and presents a wealth of information covering the present trend of modern methods of boiler feed water treatment, which heretofore has never been so thoroughly presented under the same cover.

The book should be of great value to everyone concerned with water softening and treatment. It will be found to be of great assistance to the chemist or engineer in selecting the proper type of treatment and equipment to meet his requirements.

ABSTRACTS OF WATER WORKS LITERATURE¹

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of issue, and 16 to the page of the Journal.

Tides and Their Engineering Aspects. G. T. RUDE. Proc. Am. Soc. Civ. Eng., 53: 6, 1067-1134, August, 1927. Long series of observations of tides and currents have been made throughout the world and comprehensive current and tide surveys are being made by the United States Government of all its important harbors. An accurate record of the rise and fall of the tide over a long period of time is not only of advantage, but generally necessary to a proper understanding of the conditions under which operations will be carried on. The paper is confined to the procedure and methods used by the United States Coast and Geodetic Survey in its current and tide surveys of harbors. A brief description of the instruments used is given. The tide and current data have proven of considerable value in the establishment of datum planes, in defining the mean and extreme ranges of tides, furnishing a knowledge of current flow through harbors, and the economical maintenance of channels. The article is illustrated by a number of curves and diagrams.—*John R. Baylis.*

Notes on Arched Gravity Dams. B. F. JAKOBSEN. Proc. Am. Soc. Civ. Eng., 53: 6, 1135-42, August, 1927. Formulas are developed for a gravity dam having a triangular section and a vertical up-stream face that is curved in plan. It is shown that the radius of curvature influences the stresses considerably and that it is never safe to neglect the curvature as has been customary. The middle-third theorem does not hold for arched dams.—*John R. Baylis.*

Precise Weir Measurements. E. W. SCHODER and K. B. TURNER. Proc. Am. Soc. Civ. Eng., 53: 7, 1395-1504, September, 1927. The authors present the results of new volumetric measurements of the discharge over weirs of the sharp-crested type occupying the full width of the channel. The height of the weirs ranged from 0.5 to 7.5 feet; the heads, from 0.012 to 2.75 feet; and the width of the channel, from 0.9 to 4.2 feet. The results of 2,438 volumetric

¹ Vacancies on the abstracting staff occur from time to time. Members desirous of cooperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

measurements of discharge for 1,512 different heads are given. The use of the FRANCIS weir formula:

$$Q = 3.33 L h^{\frac{3}{2}}; \text{ or, } Q = 0.623 \times \frac{2}{3} L h \sqrt{2 g h}$$

as a basic formula is substantiated for cases closely approximating the ideal weir with a truly sharp, square edge, with smooth, vertical, up-stream face near the crest, and with a deep up-stream pool, or with negligible effect of velocity of approach. The authors show the inadequacy for precise work of formulas that introduce merely the mean velocity of approach or the height of weir. The new experimental data agree with those of FRANCIS, FTELEY and STEARNS, and REHBOCK, in their evidence that BAZIN's coefficients and formula for sharp-crested weirs give too high discharges for low heads—by fully 2 to 3 per cent for heads of 0.3 to 1.2 feet. A tentative formula.

$$Q = 3.33 L \left[\left(h + \frac{Va^2}{2g} \right)^{\frac{3}{2}} + \left(\frac{Vb^2}{2g} \times h \right) \right]$$

is suggested, in which $Va^2 \div 2g$ is the mean velocity head of approach above the crest level, and $Vb^2 \div 2g$ is the mean velocity below the crest level.—*John R. Baylis.*

Historical Review of the Development of Sanitary Engineering in the United States during the Past One Hundred and Fifty Years. A Symposium. Proc. Am. Soc. Civ. Eng., 53: 7, 1585-1648, September, 1927. **Introduction.** H. P. EDDY. The development of water supply and water purification, of sewerage systems and sewage treatment works, and of refuse collection and disposal, has been coincident with the growth of cities. **Water Works.** GEO. W. FULLER. Most of the early community water-works were large wells. There were 17 water-works in the United States in 1800, all but one privately owned. The number increased to 243 in 1870, 598 in 1880, 1,878 in 1890, and over 9,000 in 1924. The percentage of privately owned plants has decreased to where they were only 30 per cent of the total in 1924. The early pipes were practically all bored logs. Cast-iron pipe began to supplant wood pipe in England about 125 years ago. THOMAS SIMPSON, about 1785, designed the first successful bell and spigot pipe with lead joints. The first pipes were not coated and in some cities the interior tuberculated badly. Dr. ANGUS SMITH introduced the tar coating in 1848. Wrought iron pipe appeared in the 'forties.' The pipe was used as a shell, being lined with cement mortar. The first important riveted wrought-iron pipe in the East was laid in Rochester, N. Y., in 1873-75. It was not until 40 or 50 years ago that much attention was paid to what may be called distribution economics. There was considerable leakage in some of the piping systems and plumbing fixtures. The leakage inside of buildings was attacked by metering. There was much opposition to meters and progress was slow. CLEMENS HERSCHEL invented the Venturi meter in the 'eighties' and furnished the first reliable device for measuring large quantities of water supplied through pipes from reservoirs and pumping stations. A brief description of the development of sources of supplies is given. In 1754, HANS CHRISTOPHER CHRISTIANSEN began the construction of the first

water-works of Bethlehem, Pa. His pump, constructed of lignum-vitae and driven by an over-shot water-wheel, raised water from a spring to tanks on the hillside above the village. The first steam pump in America was used for draining New Jersey mine. In the 'sixties,' HENRY WORTHINGTON brought out the duplex, direct-acting pump. In the 'eighties,' the Reynolds triple-expansion pump was designed. About 1900 the centrifugal pump became a really strong candidate for favor in water-works use. Electrically operated centrifugal pumps are now standard equipment. The Lawrence filter was completed in 1893, and its success in reducing typhoid fever in that city became a landmark in the train of developments which characterized the improvements in the quality of water supplies in America. What the Lawrence experiments were to the development of slow sand filters, the results of the investigations at Louisville, Ky., were in respect to rapid or mechanical filters. In 1926 there were approximately 47 slow sand and 588 rapid sand filters in the United States, serving about 23,750,000 people. Beginning in 1908, with the Boonton Reservoir supply of Jersey City, N. J., the regular use of chlorine was adopted for the purpose of destroying objectionable bacteria. It is estimated that there are in service now more than 3,200 chlorinating plants, capable of treating about 4 billion gallons of water daily. Mention is made of the methods of analysis, iron removal plants, removal of carbonic acid, water softening and filter loading. **Sewerage and Drainage of Towns.** H. P. EDDY. The author gives an excellent history of the development of sewerage systems, sewage treatment works, and drainage in American cities. In the early years the privy, the cesspool, and the drain to the nearest water-course prevailed. Fifty years ago not one of the sixty-seven cities having a population of 100,000 or more by the 1920 Census, used any method of treating the sewage. At present about 20 of these cities have built treatment plants. The work accomplished during the past 150 years in the field of sewerage and drainage of towns has been the result of the effort of relatively few individuals. **Street Cleaning and the Collection and Disposal of Refuse.** S. A. GREELEY. **Historical Notes on Land Drainage in the United States.** S. H. McCROY. **Historical Review of Development of Control of Disease-Bearing Mosquitoes.** J. A. LEPRINCE. **Changing Conceptions of Ventilation Since the Eighteenth Century.** G. T. PALMER. The latter 4 papers give excellent historical reviews of the development of these important branches of sanitary engineering.—*John R. Baylis.*

Fatigue Resistance of Welds. R. R. MOORE. Eng. News-Rec., 98: 975, 1927. Butt-welded joints in $\frac{1}{2}$ - and 1-inch tubes were tested in a rotary-beam machine. The endurance limit was distinctly lower than the metal itself and the endurance ratio (ratio of endurance limit to ultimate tensile strength) is low. Comparative tests of specimens made up solid from deposited electrode metal indicated that low endurance strength of welds cannot be explained on the assumption of inherently defective character of weld metal. From examination after fracture it is concluded that poor fusion has marked effect on endurance, so that a fatigue test may detect poor fusion where a static tension test does not. In general, the 3 test methods—gas, arc and atomic-H₂—gave results of same order.—*R. E. Thompson. (Courtesy Chem. Abst.)*

Mississippi Problem Outlined by Chief of Engineers. Eng. News-Rec., 98: 980-2, June 16, 1927. Discussion of Mississippi problem by EDGAR JADWIN, Chief of Engineers, United States Army.—*R. E. Thompson.*

Jacking Culvert Casing Under Railroad Tracks. O. F. FLUMERFELT. Eng. News-Rec., 98: 953, June 9, 1927. Iroquois Gas Corporation, Buffalo, effected 40 per cent saving in cost of laying 20-inch main under 23 railroad tracks by pushing 352 feet of 42-inch corrugated metal culvert into position and then laying main inside culvert. Three openings were made from surface. Casing permits entrance for inspection and repairs.—*R. E. Thompson.*

Basic Data for Mississippi River Problem. JOHN C. HOYT. Eng. News-Rec., 98: 956, June 9, 1927. Need of systematic study of stream-flow characteristics emphasized.—*R. E. Thompson.*

Tables Give Pipe Line Data for Road Water Supply. Eng. News-Rec., 98: 1032, June 23, 1927. Tables given for computing pipe sizes required under various conditions of pressure and distance.—*R. E. Thompson.*

Field Tests of the Discharge of Ordinary Garden Hose. J. B. MARCELLUS. Eng. News-Rec., 99: 14, July 7, 1927. Tabulated summary of 300 or more tests on the discharge of $\frac{3}{4}$ -inch garden hose through ordinary garden hose nozzle and whirling spray. Hose lengths employed were 50, 100, and 150 feet, and pressure varied from 10 to 55 pounds.—*R. E. Thompson.*

Improving Fire-Fighting Facilities in a Small Community. D. E. DAVIS. Eng. News-Rec., 98: 869, May 26, 1927. Improvement in water supply available for fire fighting in rural community of 1100 people became imperative to prevent material increase in insurance rates. System was made up of 4- and 2-inch mains, served from small pumping station having suction in concrete reservoir. Second small reservoir located at upper end of village, which gave static pressure of less than 15 pounds in center of village, was shut off at times of fire. Erection of pumping station at latter reservoir, arranged for automatic starting from switch in municipal hall, has enabled delivery in village to be doubled, maintaining adequate residual hydrant pressure.—*R. E. Thompson.*

Earth-Filled Dam Leakage Stopped by Grouting With Cement. W. H. HOLMES. Eng. News-Rec., 98: 900-1, June 2, 1927. Illustrated description of repair of earth-fill dam of Dallas-Warner reservoir of Modesto Irrigation District, Stanislaus County, Cal. Dam, which is largest of 6 forming reservoir of 27,000-acre-feet capacity, consists of earth fill with concrete core-wall and puddled core, 1600 feet long and 32 feet high through maximum section. Lining of upstream face with 4 inches of reinforced concrete and construction of cut-off wall 40 feet deep and 1000 feet long failed to stop seepage. Test holes were made and 2-inch pipes were placed in holes that showed cavities, through which cement grout was introduced first by gravity and then by pressure. Holes ranged from 12 to 40 feet deep, and 149 sacks of cement were used.

Work, which cost \$400 compared with \$85,000 for ineffective curtain wall and lining, was successful.—*R. E. Thompson.*

Driving 75-Foot, 10-Ton Concrete Piles for St. Louis Water Works Footings. JOHN C. ALLMAN. *Eng. News-Rec.*, 98: 952, June 9, 1927. Boiler house and smokestack footings for new Missouri River water works of St. Louis rest on 450 concrete piles, 16½ inches square. By taking advantage of narrow trenches piles were driven without leads, either fixed or swinging, 40-ton locomotive crane with 85-foot boom handling piles, hammer, and jet without assistance.—*R. E. Thompson.*

Cap-de-la-Madeleine Has New Water Works Pumping Plant. ROMEO MORRISSETTE. *Cont. Rec.*, 41: 82-3, 1927. Description of improvements in water supply system of Cap-de-la-Madeleine, Que., which include filtering gallery and new pumping plant. Filtering gallery, which replaces series of shallow 3-inch wells in small pond 9 feet deep, consists of trench 5 feet wide and 8 feet deep filled to depth of 2 feet with ¾-2-inch crushed limestone and to ground surface with river gravel. Composition of water given. New pumping installation has effected reduction in consumption of electricity from \$240 to \$115 per month.—*R. E. Thompson.*

Concrete Cradles Increase Pipe Support. *Eng. News-Rec.*, 98: 1072, June 30, 1927. Brief data from Bulletin 80, Iowa State College of Agriculture and Mechanic Arts. Use of concrete cradles for large-size pipe conduits increases supporting strength of pipe to about 1½ times that obtained when pipe is laid in trenches in ordinary manner. Thick cradle with high sides was found to give most supporting strength. Reinforcing cradle in flat plane seemed more effective than curving it to parallel pipe surface, although cradles without reinforcing were as effective as those with reinforcing.—*R. E. Thompson.*

Flow Tests of Winnipeg Aqueduct. A. L. COLLINS. *Eng. News-Rec.*, 99: 27, July 7, 1927. Criticism of methods used in measuring flow in Winnipeg aqueduct and reply to same by J. H. GRANT.—*R. E. Thompson.*

Almost Complete Utilization of Small Pennsylvania Stream. FARLEY GANNETT. *Eng. News-Rec.*, 98: 1057, June 30, 1927. South Branch of Roaring Creek, just outside coal measures, having drainage area of 12.2 square miles, is drawn upon by 3 companies to supply Shamokin and other towns, coal mines, and industries. Roaring Creek Water Company and Bear Gap Water Company, which are affiliated, supply 6.5 and 2.2 m.g.d. respectively and Wyoming Valley Water Supply Company, supplies 1 m.g.d. As average safe yield is only 11 m.g.d., or 0.9 m.g.d. per square mile of drainage area, this leaves only 1 m.g.d. safe margin. Four reservoirs provide storage of 1,965 m.g., or 161 m.g. per square mile. Chlorination is employed.—*R. E. Thompson.*

Efficient Cutting Outfit for Salvaging Pipe Lines. *Eng. News-Rec.*, 98: 875, May 26, 1927. Brief illustrated description of pipe cutting apparatus

designed by N. E. WAGNER for salvaging oil pipe lines, in which 2 oxyacetylene torches are mounted at 45° angles so that resulting ends of pipe lengths will be beveled for future welding. Torches are slowly revolved about pipe by small crank and gear wheels.—*R. E. Thompson.*

Cutting Large Cast-Iron Pipes by Machine. CHAS. P. McGRATH. Eng. News-Rec., 98: 870, May 26, 1927. Brief illustrated description of pipe cutting machines ranging in size from 24 to 48 inches in diameter purchased by Detroit Dept. of Water Supply. It takes 3 men only 1½ hours to set up machine on 42-inch or 48-inch pipe, and 1 man ½–1 hour to make cut. Another desirable feature is impossibility of cracking pipe. Cutting edge of tool is ¼ inch wide, thus total clearance of ½ inch is provided for removing section after cutting.—*R. E. Thompson.*

Current Meter Investigations Needed. PAUL E. HOFF. Eng. News-Rec., 99: 28, July 7, 1927. Discussion of current meter and its use in which need of investigation of fundamental requirements for good meters is emphasized.—*R. E. Thompson.*

Water-Driven Booster Pumps in Use at Louisville, Ky. CHAS. B. BURDICK. Eng. News-Rec., 98: 873, May 26, 1927. Brief description of new installation at Crescent Hill pumping station of Louisville Water Company, consisting of 10-inch centrifugal pump direct-connected to 12-inch, 125-h.p. water motor delivering 3000 g.p.m., taking water at 115-foot head and boosting it 116 feet. Motor receives water from city mains under head of 115 feet. Over-all efficiency of motor and pump is 64 per cent at 3000 g.p.m., and 64.6 per cent at 2100 g.p.m. and 139-foot net head which prevails at night when pressure at main station is reduced. Installation will supply elevated tank of 1 m.g. capacity and Lakewood high-service district which consumes about 2 m.g.d. Fact is sometimes overlooked that power developed in water pumped by high-duty pumping engines may be employed for miscellaneous purposes with better economy than is possible by using power developed directly from steam. This is particularly true where high-lift pumps are relatively large and miscellaneous power uses relatively small.—*R. E. Thompson.*

Leakage Test of 48-Inch Cast-Iron Water Main in England. T. F. YOUNG. Eng. News-Rec., 98: 1033, June 23, 1927. Methods of testing and results given. Contract required that each individual joint be tested to pressure of 260 pounds per square inch before being backfilled. On completion of definite lengths, pipe and joints were required to withstand water pressure of 140–200 pounds per square inch for 30 minutes with maximum loss 50 gallons per mile per hour. Pipe sections were 12 feet long, of 48-inch internal diameter and weighed approximately 10,000 pounds. Joints are leaded and were calked by hand. Main was charged with water from pressure main alongside and pressure was raised by gasoline-driven force pump and maintained by means of hand pump taking water from calibrated vessel. Method of holding cap for testing described and illustrated.—*R. E. Thompson.*

Magnetic Inspection of Steam Turbine Disks. J. A. CAPP. Eng. News-Rec., 99: 24, July 7, 1927.—*R. E. Thompson.*

Testing Proposed Ground Water Supply for Beatrice, Neb. HARRY P. LETTON. Eng. News-Rec., 98: 870, May 26, 1927. Considerable difficulty has been experienced during past 40 years in obtaining satisfactory water supply for Beatrice, Neb., a town with about 10,000 population located on Big Blue River. Present supply is obtained from well 3 miles west of city producing 0.75 m.g.d., which is considerably less than summer demand. Scheme for supplying filtered river water was defeated by vote of people 3 years ago. Investigations for new ground water source have been conducted since that time and favorable site located 5 miles west of town. To test probable yield of proposed location, 13 test holes were sunk, one being 12 inches in diameter to admit pump cylinder. Water level measurements were made before, during, and after pumping by means of length of rubber-covered wire fastened with friction tape to 100-foot steel tape. One end of tape and wire were rolled in sheet lead and soldered in place and wire then cut off even with end of tape, but insulated from it. Other ends were connected to 45-volt dry cell and voltmeter was inserted in circuit. When weighted tape was lowered into well, circuit was completed as soon as it touched water surface. It is believed that continuous minimum supply of 0.5 m.g.d. could be obtained from new site, and that 2 to 4 times this amount could be obtained by increasing number of wells and area drawn from.—*R. E. Thompson.*

Providing Additions and Extensions to Existing Water Pumping Station. WM. L. HAVENS. Eng. News-Rec., 98: 872-3, May 26, 1927. Brief illustrated description of extensive additions made during past year to Alliance, O., pumping station, which was constructed 25 years ago and remodeled in 1917. New equipment includes two 350-h.p. water-tube boilers equipped with mechanical stokers, and 10-m.g.d. high-service pumping unit. Improvements cost about \$150,000, and their installation has effected yearly saving of \$7,000 in cost of operation.—*R. E. Thompson.*

Water-Cement Ratio and Maximum Strength. T. KUO. Eng. News-Rec., 98: 958, 1927. A critical discussion of the water-cement ratio theory. When the water-cement ratio is altered, another variable is introduced, namely, the rate of gaining strength for concrete of different consistencies. A dry mixture generally develops greater strength in a shorter period; therefore ABRAMS' result is not surprising.—*R. E. Thompson. (Courtesy Chem. Abst.).*

Filter Operation in a Small Community. NICHOLAS S. HILL. Eng. News-Rec., 98: 868, May 26, 1927. Description of small automatically-operated filter plant recently constructed at Bethel, Conn., at cost of about \$20,000. Raw water is bacteriologically safe but objectionable because of iron, color, tastes, and odors. Aeration followed by coagulation with alum and soda ash and filtration was obvious remedy, with plant located at reservoir 2½ miles from town. Operation of plant is controlled by elevation of water in filtered water basin, float valves being provided on raw water inlet, filtered water

outlet, and on each outlet from orifice tanks for chemical solutions. Operator visits plant twice each day to wash filters, prepare chemical solutions and make adjustments. Coagulation basin provides 4 hours' detention at 100,000 g.p.d. rate. There are two filters, each of 100,000-g.p.d. capacity, and filtered water basin has capacity of 50,000 gallons.—*R. E. Thompson.*

Laying Water Main Across Small Stream. D. S. McGLASHON. *Eng. News-Rec.*, 98: 954, June 9, 1927. Brief description of method employed in laying two 6-inch cast-iron pipe lines across Little Platte River during construction of distribution system for new water supply at Smithville, Mo. Work was carried out when river was frozen, trench being excavated by hand by men on the ice. Joints were made on bank and pipes were pulled across river by means of stump puller and cable as each 12-foot section was added.—*R. E. Thompson.*

Rapid Field Method of Determining Characteristics of Sand. CLOYD M. CHAPMAN. *Eng. News-Rec.*, 98: 955, 1927. New type of simple apparatus for rapid determination of surface moisture, voids, or apparent sp. gr. of fine aggregate.—*R. E. Thompson. (Courtesy Chem. Abst.)*

Wash Water Reservoir Control at Cleveland, Ohio. L. A. MARSHALL. *Eng. News-Rec.*, 98: 866, May 26, 1927. Water for filter washing at Division Ave. plant is drawn from 400,000-gallon covered concrete reservoir consisting of two rectangular basins located on hillside above plant. Reservoir is filled through 16-inch cast-iron pipe line, direct-connected to 48-inch low pressure distribution main. The 16-inch line discharges into float chamber through altitude float valve, from which water passes through two 16-inch hand-operated valves into reservoir basins. Disturbance created by discharge in float chamber caused sticking of valve, resulting in reservoir overflowing or emptying. Transferring discharge into second basin by means of 16-inch pipe line, elevation being transmitted back to float chamber through first basin, has eliminated the rapid fluctuations in level in float chamber and has remedied the condition.—*R. E. Thompson.*

Removing Sand From Gravity Supply Line. ROBT. B. MORSE and CARL A. HECHMER. *Eng. News-Rec.*, 98: 868-9, May 26, 1927. Water filtration plant at Hyattsville, Md., which furnishes water to Washington Sanitary District, is fed through 18-inch gravity supply line of vitrified pipe, laid on flat slope of 0.5 feet per 1000, about 2 miles long. During excessive rainfall, sand is carried into and deposited in pipe, reducing its capacity. To correct this condition a sand trap was constructed below screen chamber, 24 feet long and 6 feet wide, converging at ends to width of 24 inches where pipe enters and leaves. Bottom at inlet end is 3 feet below invert of pipe, and 2 feet below at outlet. Trap is cleaned out about once a month.—*R. E. Thompson.*

Relation between Fineness Modulus and Concrete Strength. F. S. BESSON. *Eng. News-Rec.*, 98: 956, 1927. It is shown that both the fineness modulus and surface area systems of measuring concrete aggregates are rule of thumb methods and that their use does not guarantee the strength of the concrete produced.—*R. E. Thompson. (Courtesy Chem. Abst.)*

New Centrifugal Pumps Surpass Previous Efficiency Records. WM. SCHWAN-HAUSSER. Eng. News-Rec., 98: 1015-7, June 23, 1927. Illustrated description of two 36-inch motor driven centrifugal pumps installed in Detroit, Michigan. Capacities of 50 and 70 m.g.d. per 24 hours against 170-foot head were specified, specifications also requiring that pumps have same casing and be so designed that smaller might later be converted to capacity of larger with no change except impeller. Motors are of synchronous type with direct-connected exciters, motors running at 514 r.p.m. with full-load ratings of 2,050 and 2,600 h.p. respectively. Double-section volute type pump with horizontal shaft was selected. The 50-m.g.d. unit showed overall maximum efficiency of 84.7 per cent and pump efficiency of 88.5 per cent. This is a world's record. The 70-m.g.d. unit—largest motor-driven water works pump, with respect to horsepower, installed to date—showed maximum combined efficiency of 82.7 and pump efficiency of 86 per cent.—*R. E. Thompson.*

Supplementary Notes on Detroit's Pumps. W. C. RUDD. Eng. News-Rec., 98: 1017, June 23, 1927. Priming pipes of main pumps are connected into suction chambers and piped to overhead closed vacuum tank. Both pumps are thus kept automatically primed at all times. Motors are of remote-control hand-start type with motor-operated switching equipment located in switch house near pump pit. Each pump has duplicate power feeders so arranged that power may be secured from either of 2 large transformers.—*R. E. Thompson.*

Designing Equivalent Concrete Mixtures. F. H. AUSTIN. Eng. News-Rec., 98: 914, 1927. Formula given based on CRUM'S "sand method."—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Developing a 10-M.G.D. Water Supply from Wells and Surface Sources. Eng. News-Rec., 98: 904-6, June 2, 1927. Old well water supply system of Amarillo, Texas, was designed to serve population of 15,000 and was adequate in 1920. Present population is 50,000, 35 per cent of which has been added in past 18 months, and system is, of course, now overworked. New 10-m.g.d. system is nearing completion at cost of about \$2,100,000 and negotiations are under way for purchase of old privately owned system. Suitable site was located 15 miles from city, where 7 wells have now been drilled, total capacity being 7 m.g.d. A 3-m.g.d. surface supply for emergency use has been made available by construction of impounding earth-fill dam 45 feet high above bed of Palo Duro Creek with crest length of 1650 feet. Water from wells is pumped to receiving reservoir just below dam, which can also be fed from impounding reservoir. Pumping station nearby delivers water from receiving reservoir to 15.7-mile 30-inch cast iron pipe line which for most part is under gravity head. Second 5-m.g. concrete receiving reservoir is located at city end of line. Wells, 6 of which are operated by air lift and 1 by motor-driven axial flow pump, are of commercially known "air-made" type in which large cavity made by compressed air around perforated strainer pipe is filled with gravel fed from top. Construction of wells described in detail. Chlorinating equipment has been provided at impounding reservoir pumping station.—*R. E. Thompson.*

Building a 16-Mile Levee on the Colorado Delta. Eng. News-Rec., 98: 1066-7, June 30, 1927. Illustrated description of construction of levee extending southwest from point on Pescadero levee. In 40-day construction period 1,000,000 cubic yards of fill were placed.—*R. E. Thompson.*

Studies of the Permeability of Porous Plates. WALLACE L. HOWE. Eng. News-Rec., 99: 18-9, 1927. A method is described for determining the permeability of porous plates, and the effect of temperature on permeability is discussed. The permeability of a plate is expressed in terms of the number of cubic feet of air passing through 1 square foot in 1 minute under a differential head of 2 inches of water. It was found that the velocity was directly proportional to the pressure head and therefore in agreement with Poiseuille's law governing stream-line flow of fluids through capillaries. From this law it would be expected that the permeability would be inversely proportional to the viscosity of the air, which increases with the temperature. Tests showed that the true permeability decreased proportionally with increase in temperature. A corrective chart developed from the latter tests is given.—*R. E. Thompson. (Courtesy Chem. Abst.)*

West Palm Beach Water Co. Builds 20-M.G.D. Purification and Pumping Plant in Ten Months. CHAS. F. RUFF. Eng. News-Rec., 98: 1048-52. In 1921 Palm Beach and West Palm Beach were adequately served by 3-m.g.d., filtration plant. In 1924-5 additional 3-m.g.d. unit, then just completed, failed to meet peak demand of 7 m.g.d., additional 1 m.g.d. being supplied from wells. In 1925-1926 peak demand was nearly 9 m.g.d. and increase in rates was granted to enable construction of new plant. A 20 m.g.d. plant, with provision to increase to 40 m.g.d., was decided upon and site selected was immediately west of old plant on shore of Clear Lake, on lake side of bulkhead where water is 2-6 feet deep. Location necessitated extensive dewatering, which was effected by construction of sand dike, lowering ground water by pumping from wells sunk on shore and taking care of seepage through dike with 6-inch centrifugal pump. Two coagulation basins, begun in 1925, were finished with 1926 additions. Basins are of 1½ m.g. capacity each, providing 8 hours' retention of 9 m.g.d. flow. There are four 5-m.g.d. reinforced concrete filters with perforated pipe underdrains, sand employed having effective size of 0.41 mm. and uniformity coefficient of 1.53. Vertical rise of wash water is 18 inches per minute, at which rate sand expands about 20 per cent. Pure water reservoir has capacity of 0.8 m.g. Six centrifugal pumps were installed in new pumping station: 3-, 7-, and 15-m.g.d. high-lift pumps and same capacities in low-lift, all driven by 4200-volt synchronous motors with direct connected exciters. Tests showed over-all efficiencies from 74.5 per cent for 3-m.g.d. high-lift to 78.8 per cent for 15-m.g.d. high-lift. Costs were: filters \$178,000; effluent aerator \$36,000; reservoir \$61,000; coagulation basins \$202,000; total \$877,000.—*R. E. Thompson.*

Wanaque Aqueduct and Watershed-Yield Controversy. Eng. News-Rec., 98: 1062-5, June 30, 1927. Reports of PRATT and SHERREED and of JOHNSON

regarding Wanaque development of North Jersey District Water Supply Commission are reviewed. Chief points in controversy are: employment of concrete aqueduct or twin "smooth bore" steel pipe lines; yield of watershed; capacity of aqueduct or pipe line required; and estimated cost of work. District is under contract with 8 municipalities to build storage reservoir on Wanaque River of sufficient size to deliver average of 100 m.g.d. to municipalities at cost not exceeding \$20,350,000. Aqueduct, as planned, would be 20.66 miles in length.—*R. E. Thompson.*

Winter Setting Temperature of Concrete. Eng. News-Rec., 98: 1065, June 30, 1927. Data from Bulletin 8, Michigan Engineering Experiment Station, given briefly. Concrete made with standard portland, alumina, and high early strength portland cements reached freezing point 130, 140, and 144 hours after mixing respectively. Concluded that portland cement concrete may be poured safely in freezing weather without application of heat during setting by using heavy forms, properly covering exposed surfaces and maintaining mixing temperatures of not less than 80°F.—*R. E. Thompson.*

Protective Linings for Cast-Iron Pipes. CHAS. W. SHERMAN. Eng. News-Rec., 98: 872, 1927. Brief discussion. Cement lined pipes have been found satisfactory during past 4-5 years. Linings used in this country may not be of sufficient thickness to be permanent. In England cement linings approximating $\frac{1}{2}$ inch are employed. Talbot coating, used in Great Britain, consists of mixture of asphalt and ground rock, applied hot by centrifugal force to depth of $\frac{1}{4}$ inch. An extremely smooth surface is provided and coating adheres with great tenacity. Coatings of chemically treated glass, reported to have been found resistant to sea water for 10 years, have also been suggested.—*R. E. Thompson. (Courtesy Chem. Abst.).*

Dragline Mucking in Rock Tunnel for New Chicago Intake. Eng. News-Rec., 98: 860-3, May 26, 1927. Description of construction of intake tunnel in Chicago and of dragline mucking system developed, which has effected marked gain in speed and economy over hand mucking. Present work covers 3 miles of tunnel, but 12 miles of extension is projected. Tunnel is horseshoe in section, 13-16 feet in equivalent diameter, and is 150 feet below water, with 40-60 feet rock cover. Former practice was to build supply tunnels in diagonal alignment, passing under private property without regard for surface ownership. This has led to trouble in some cases and has been declared trespass. Policy of locating all water tunnels under streets and of providing for earliest replacement and abandonment of existing diagonal tunnels has been adopted.—*R. E. Thompson.*

Welding Finds Extensive Application in All Oil Field Work. Eng. News-Rec., 98: 972-5, June 16, 1927. Practice of welding large pipe lines is growing very rapidly, and pipe which is not too badly pitted is repaired by this method. Boiler repairs are almost exclusively made by welding. Scrap pipe is used for variety of welded construction work.—*R. E. Thompson.*

Removing Sand from Well Water. W. W. BRIGDEN. *Eng. News-Rec.*, 98: 869, 1927. Well pumping systems should not be connected directly to distribution systems, but should discharge into basin of sufficient size to allow sand and other solids to settle.—*R. E. Thompson. (Courtesy Chem. Abst.).*

New 12-M.G.D. Water Purification Plant for Oakland. *Eng. News-Rec.*, 98: 857-60, May 26, 1927. Detailed illustrated description of additional 12-m.g.d. plant just put in commission by East Bay Water Company, main features of which are 105-nozzle aerator, mechanical alum mixers, choice between 3 methods of operating coagulating and settling basins, 4 large filters which are divided and operated in half, single operating table for 8 half-filters, and reclamation of wash water. Plant treats water from 16-m.g. upper San Leandro impounding reservoir. Coagulation units are of type developed for Sacramento plant (*Eng. News-Rec.*, June 2, 1921, p. 924), and consist of 4 circular concrete tanks, 21 feet in diameter and 21 feet deep, each equipped with variable-speed motor-operated stirring mechanism which imparts swirling rotary motion to water. Water velocities as high as 3 feet per second may be developed. Filters operate under 8- to 15-feet head at rate of 110 m.g.d. per acre. In addition to greater simplicity, analysis indicated that bifurcated units result in considerable saving in first cost. Experience at other plant has shown that air-agitation preliminary to water wash is highly desirable because of manganese present in raw water, which forms sticky hydrate not easily removed. Under-water cracking results if manganese is not removed. Underdrains are of red brass. Provision has been made for pre- and post-chlorination.—*R. E. Thompson.*

Constant Temperature-Humidity Box for Storing Cement Specimens. *Eng. News-Rec.*, 98: 953, June 9, 1927. Brief description of storage box developed at Bureau of Standards.—*R. E. Thompson.*

Some Metallurgical Problems of the Water Works Engineer. W. E. MILLINGTON. *Water and Water Eng.*, 28: 233, 1926. From *Chem. Abst.*, 20: 3202, October 10, 1926.—*R. E. Thompson.*

Cause of the Blackening of the Sand in Parts of the Clyde Estuary. D. ELLIS. J. Roy. Tech. Coll. Glasgow, 1925, 2, 144-56. From *Chem. Abst.*, 20: 3203, October 10, 1926. In various localities in Clyde estuary the sand is deep black in color and when freshly gathered has strong odor of hydrogen sulfide. On exposure to air it slowly loses its black color and becomes brown. Fresh sand swarms with saprophytic bacteria and contains sufficient moisture and organic matter to provide for their development, during course of which hydrogen sulfide is evolved. This gas reacts with ferruginous minerals in the sand and with iron compounds brought down by the river, both in solution and suspension, and iron sulfide so formed is deposited on sand grains, causing characteristic blackness.—*R. E. Thompson.*

Drainage Provisions in Gibson Dam. *Eng. News-Rec.*, 98: 976, June 16, 1927. Brief description of provisions made for drainage in Gibson dam on

north fork of Sun River, 80 miles west of Great Falls, Mont. Structure will be 195 feet high and 900 feet long and will create reservoir of 90,000 acre-feet capacity, capable of being increased to 105,000 by drum gates on spillway, to be installed later if necessary. Spillway capacity will be 50,000 second-feet.—*R. E. Thompson.*

Least Error in V-notch Weir Measurements when Angle is 90 Degrees. MORROUGH P. O'BRIEN. *Eng. News-Rec.*, 98: 1030, 1927. Mathematical proof is given that 90° V-notch will give least error in computing discharge over triangular weirs.—*R. E. Thompson. (Courtesy Chem. Abst.).*

Sixtieth Annual Report of the Commissioners of Water Works in the City of Erie, Pa., for Year Ending December 31, 1926. 78 pp. Annual report of Erie water works, consisting of brief outline of major improvements made during year and detailed statistics relative to financial dealings, plant operation, and extensions. Maximum daily pumpage was 33,437,400 and average 24,717,806, an increase of 3.04 per cent, representing average daily per capita consumption of 199.3 gallons on basis of population supplied (124,000), and 114 gallons after deducting water which was delivered through meters to industrial and large commercial users, which amounted to 42.8 per cent of total pumpage. An addition of \$232,857.12 was made to surplus on year's operation, and also an additional amount of \$3,552.02 applicable to prior years, bringing total surplus to \$5,183,093.65. Cost of collecting, purifying, and pumping water, including depreciation, averaged \$22.065 per m.g. Number of gallons pumped per pound of coal was 259. Average amounts of alum and hypochlorite used during year were 0.15 grain per gallon and 3.6 pounds per m.g. respectively. Of 303 one-cc. samples of raw water examined, 72 contained *B. coli*, while all of the 605 one- and ten-cc. samples of filtered water examined were negative. Value of water furnished for municipal purposes without cost during year was \$49,892.02. Brief description of works and schedule of rates is appended.—*R. E. Thompson.*

Leaking Chlorine Cylinders. *Eng. News-Rec.*, 98: 955, June 9, 1927. Electro Bleaching Gas Company suggests pouring water over nozzle as temporary means of stopping leaks in chlorine cylinders. Evaporation of liquid chlorine will cause water to freeze around open valve reducing flow of gas. Although ice will soon melt, cylinder can in meantime be safely handled and leak stopped.—*R. E. Thompson.*

Physical-Chemical Determinations by Accelerated Precipitation. M. DUBOIX. *Mitt. Lebensm. Hyg.*, 17: 133-40, 1926. From *Chem. Abst.*, 20: 3196, October 10, 1926. In conductivity determinations in physical-chemical volumetric analysis, where often extremely dilute solutions are used, time of complete reaction is great. Addition of certain amount of precipitate to be formed in some cases decreases time of analysis from several hours to few minutes. In determination of calcium in drinking water, oxalate method gives erratic results if magnesium content is in excess of calcium. DUBOIX precipitates calcium by means of sodium ammonium tartrate. As reaction accel-

erator 1 gram of calcium tartrate and a little alcohol are added.—*R. E. Thompson.*

A Review of Questions Concerning Sewage. J. WERDER. *Tech. Ind. u. Schweiz. Chem. Ztg.*, 1926, 62-9; *Mitt. Lebensm. Hyg.*, 17: 182-92, 1926. From *Chem. Abst.*, 20: 3203, October 10, 1926. Tests necessary to determine character of polluted stream. Hydrogen sulfide is determined by nearly neutralizing 20 cc. of water with hydrochloric acid, and adding 0.3 cc. of p-aminodimethylaniline (1 per cent solution) and 0.3 'cc. of ferric chloride (1 per cent). A red to violet color is formed.—*R. E. Thompson.*

Manchester Water Works. W. F. H. CREBER. *Water and Water Eng.*, 28: 238, 1926. From *Chem. Abst.*, 20: 3202, October 10, 1926. Water is obtained from two impounding reservoirs and third is to be constructed, giving total capacity of 30 billion gallons. Distribution system is very complicated and requires force of 700 people for additions and repairs. Difficulty has been encountered recently by reservoirs and aqueducts being undermined by coal companies.—*R. E. Thompson.*

Apparatus for Proportioning Chemicals Used for Purifying Water, or for Other Purposes. C. F. WALLACE. U. S. 1,593,109, July 20. From *Chem. Abst.*, 20: 3102, October 10, 1926.—*R. E. Thompson.*

Mitigation of Electrolysis (Corrosion) in Louisville. E. G. NOREL. *Elec. World*, 88: 365-6, 1926. From *Chem. Abst.*, 20: 3135, October 10, 1926. Two features of electrolysis mitigation are (1) reduction of flow of current through earth, (2) reduction of anode areas to minimum in order to reduce area of destructive corrosion. It was found that current was leaving a subterranean cable sheath and returning to railroad rail. At point near railway substation, cable sheath was electrically connected to rail and negative bus in station. It was then found that cable was negative to rails throughout and electrolysis was mitigated.—*R. E. Thompson.*

The Action of Salt Solutions on the Ferrous Metals. RENÉ GIRARD. *Compt. rend.*, 183: 213-4, 1926; cf. *C. A.*, 20: 573. From *Chem. Abst.*, 20: 3151, October 10, 1926. Shown that 0.3 per cent magnesium chloride is as corrosive as 2 per cent sodium chloride. Cast iron is more resistant than steel and aëration has little effect. Magnesium sulfate in 0.175 per cent solution is similar to magnesium chloride and shows no tendency to cause rusting. A 0.18 per cent solution of calcium chloride in aërated solutions corrodes steel, but slowly forms protective coating on cast iron. In deaërated solution it rusts cast iron about twice as fast as steel.—*R. E. Thompson.*

The Fundamental Principles of Corrosion. U. R. EVANS. *Metal Ind.* (London), 29: 130-2, 152; *Chemistry and Industry*, 45: 504-8, 1926. From *Chem. Abst.*, 20: 3150, October 10, 1926. Review.—*R. E. Thompson.*

The Walton Filters and Pumping Station of the Metropolitan Water Board. Engineering, 122: 9-12, 40-3, 1926. From Chem. Abst., 20: 3202, October 10, 1926. Detailed description of new filter beds and accessories, and new pumping plant.—*R. E. Thompson.*

Formation of Sodium Carbonate on Contact of Iron with a Solution of Sodium Sulfate and Air: Mechanism of Rusting of Iron. V. A. KISTYAKOVSKII. J. Russ. Phys.-Chem. Soc.; Chem. Part, 57: 97-106, 1925. From Chem. Abst., 20: 3150, October 10, 1926. When iron is partially immersed in sodium sulfate solutions the immersed portion partly dissolves with formation of iron sulfate, whereas the emerging portion acquires an alkaline reaction due to formation of sodium carbonate. Particularly good yields of sodium carbonate were obtained with iron which had commenced to rust, but very rusty iron did not give the salt. Process is favored by presence of excess of carbon dioxide in air. In absence of evaporation and concentration there is no formation of crystals of soda. Addition of carbon dioxide to air in experiments with closed vessels did not cause formation of noticeable amounts of soda, but accelerated process of rusting of iron. Theory of formation of soda is: When iron is incompletely immersed in ferrous sulfate a galvanic couple is formed. Sodium carbonate is then formed by action of local galvanic currents circulating along surface of iron plate if it is partly covered with thin layer of oxides. Bare spot on plate is negative pole, i.e., spot where the iron dissolves; and spot covered with oxides is positive pole. Presence of oxygen and carbon dioxide at positive terminal strengthens local currents, accelerating process. When operating so that evaporation of sodium sulfate solution cannot occur (in closed vessels) the sodium carbonate formed gradually drops into the electrolyte where it reacts with iron sulfate and oxygen to form iron oxide and carbon dioxide. Acceleration of rusting of iron due to excess of carbon dioxide is caused by circumstance that free energy of galvanic couple—iron/electrolyte/sodium sulfate +—is increased on account of temporary formation of sodium carbonate. As long as thin layer of oxides covering whole surface of iron remains unbroken rusting will not take place.—*R. E. Thompson.*

Investigation on the Corrosion and Rusting of Iron and Steel. R. GIRARD. Rev. métal., 23: 361-7, 407-17, 1926; cf. C. A., 19: 3070; 20: 573. From Chem. Abst., 20: 3151, October 10, 1926. More detailed description of work and discussion of results.—*R. E. Thompson.*

Deodorizing and Disinfecting Action of Electrolytic Sodium Hypochlorite on Industrial Waste Liquors and Sewage. ADOLF GRAUMANN. Desinfektion, 11: 43-6, 1926. From Chem. Abst., 20: 3054, September 20, 1926. Sodium hypochlorite is inexpensive and very efficient deodorant and disinfectant. Anthrax were killed within 12 hours by 0.5 per cent solution.—*R. E. Thompson.*

Pulp- and Paper-Mill Discharge in Relation to the Purity of Streams. V. P. EDWARDES. Paper Mill, 49: No. 24, 10, 12, 42, 44, 1926; Paper Trade J., 82: 24, 43-6, 1926. From Chem. Abst., 20: 3080, September 20, 1926. Discussion of problem of stream pollution by mill effluents with special reference to legal aspects.—*R. E. Thompson.*

Straw-Board and Straw-Paper Waste Water. H. G. FUNSETT. *Paper Ind.*, 8: 461, 1926; *Paper Trade J.*, 82: 24, 46-7, 1926. From *Chem. Abst.*, 20: 3080, September 20, 1926. Brief review of progress in elimination and disposal of strawboard mill waste.—*R. E. Thompson.*

Softening Water. F. SCHMIDT. U. S. 1,590,913, June 29. See *C. A.*, 19: 2717. From *Chem. Abst.*, 20: 3055, September 20, 1926.—*R. E. Thompson.*

Composition for Removing Incrustations from Steam Boilers, etc. M. E. STEWART. U. S. 1,590,915, June 29. From *Chem. Abst.*, 20: 3055, September 20, 1926. Lead acetate 3, sodium carbonate 40, and gum japonica 50 parts.—*R. E. Thompson.*

Studies in Pernicious Anemia. I. E. W. MONTGOMERY. *Can. Med. Assoc. J.*, 16: 244-50, 1926. From *Chem. Abst.*, 20: 3186, October 10, 1926. Distribution of cases suggests long-continued drinking of water slightly alkaline and containing excess calcium, magnesium, chloride, sulfate, etc., as a causative agent leading to achlorhydria, which may subsequently lead to pernicious anemia.—*R. E. Thompson.*

Determination of pH in Mineral Waters. I. R. NASINI and C. PORLEZZA. *Ann. chim. applicata*, 16: 156-66, 1926. From *Chem. Abst.*, 20: 3053, September 20, 1926. Review and discussion of methods of determining pH and factors which render determinations unreliable leads to view that there is no precise method for determining pH of mineral waters. Physico-chemical measurements, such as depression of freezing point and the electrical conductivity are more reliable criteria of variations in composition of mineral waters. H-ion concentration measurements are of considerable value in determining carbon dioxide or hydrogen sulfide content and changes on standing of carbonated or sulfurated waters ("aging"). Loss of carbon dioxide from carbonated waters exposed to air can be followed by progressive increase in pH. Exposed to air, the pH of some sulfurated waters decreases because of partial oxidation of hydrogen sulfide first to sulfur and this in turn to sulfuric acid. If, however, carbon dioxide is also present in large enough amount and is evolved, there may be an increase in pH, and in general pH decreases or increases according to which phenomena predominates.—*R. E. Thompson.*

Operation of Indoor Swimming Pools. R. F. HEATH. *Canadian Engineer*, 50: 499-502, 1926. From *Chem. Abst.*, 20: 3053, September 20, 1926. Principal features in design and operation of 16 indoor swimming pools in Toronto described. Three of pools are operated on fill-and-draw principle while remainder are equipped with circulating and filtration systems. In latter, alum is added in amounts from 0.06 to 0.52 grain per gallon. The water in all pools is disinfected, chloride of lime being most common reagent. Experience at Toronto has indicated that residual chlorine content of 0.2 p.p.m. is sufficient to destroy organisms introduced during bathing period.—*R. E. Thompson.*

Germicide and Sterilizing Agent. C. H. H. HAROLD. U. S. 1,590,372, June 29. From *Chem. Abst.*, 20: 3055, September 20, 1926. Solution of chlo-

rine is added to solution of diammonium phosphate or other ammonium salt in proportion corresponding to 0.025-2.0 parts NH_4 to each part of chlorine. Suitable for sterilizing water or sewage.—*R. E. Thompson.*

The Radioactivity of the "La Toja" Springs. F. D. de RADA. *Añales soc. españ. fis. quím.*, **24**: 259-66, 1926. From *Chem. Abst.*, **20**: 2944, September 20, 1926. Eight springs of "la Toja" baths showed Rn content of 3.7-7.9 millimicrocuries per liter and fixed radioactivity by the ENGLER and SIEVEKING apparatus of 26-122 v.-hours per liter. Mud from 5 springs contained $190-490 \times 10^{-12}$ Ra per gram.—*R. E. Thompson.*

New Radioactive Springs in the Puy-de-Dôme (France). CH. JACQUET. *Compt. rend.*, **182**: 1398-1400, 1926; cf. *LEPAPE, C. A.*, **15**: 796. From *Chem. Abst.*, **20**: 2944, September 20, 1926. One spring with flow of 140 liters per hour had average Rn content of 105.75 millimicrocuries per liter.—*R. E. Thompson.*

Sterilization of Drinking Water for Plantations. G. W. P. LIETH. *Arch. Suikerind.*, **34**: 452-4, 1926; cf. *C. A.*, **17**: 3393; **20**: 465. From *Chem. Abst.*, **20**: 3053, September 20, 1926. It was found in France during the war that 0.1 p.p.m. of active chlorine is sufficient for practical purposes, and that this concentration does not appreciably affect taste. It is best to use solution of sodium hypochlorite, prepared by treating sodium carbonate or sulfate solution with chloride of lime and filtering.—*R. E. Thompson.*

Water Treatment for Raw-Water Ice Plants. W. N. WATERMAN. *Power Plant Eng.* **75**: 8, 30, 1926. From *Chem. Abst.*, **20**: 3053, September 20, 1926. Calcium carbonate and bicarbonate, magnesium carbonate, bicarbonate, chloride and sulfate, iron and organic matter are cause of objectionable gray to dark brown deposits on ice. Treatment with lime leaves calcium sulfate and chloride, which are not objectionable. No benefit is derived from use of soda ash because calcium salts are no more objectionable than sodium salts. Zeolite treatment is not satisfactory because mineral content is not reduced. Use of softened water is cheaper because core water need not be changed so often.—*R. E. Thompson.*

The Effect of Pumps on the Maintenance of Pipe Lines. J. D. KEILEY and E. M. GRIME. *Railway Eng. and Maint.*, **23**: 4, 171. Continuous flow of centrifugal pumps eliminates trouble caused by pulsations in reciprocating pumps. Maintenance condition has greater influence than type of pump.—*R. C. Bardwell.*

Trouble with Float Valves from Freezing. J. R. HICKOX and A. I. GAUTHIER. *Railway Eng. and Maint.*, **23**: 5, 216. Trouble can be relieved to some extent by circulation of water through body of valves but altitude valves properly protected are recommended in preference.—*R. C. Bardwell.*

A Direct Connected Centrifugal Pump driven by a Fordson Tractor Motor. Anon. *Railway Eng. and Maint.*, 23: 5, 218. The D. T. & I. Railroad has six pumping installations where centrifugal pumps are direct connected with flanged coupling to Fordson tractor motors operating on kerosene. Relative economies are claimed.—*R. C. Bardwell.*

Large Pumping Plant on Wheels of Great Service in Flood. C. R. KNOWLES. *Railway Eng. and Maint.*, 23: 6, 244. The Illinois Central Railroad developed a portable emergency pumping plant consisting of one 18-inch, one 12-inch, and one 10-inch belt driven centrifugal pump operated by 200 h.p. and 75 h.p. electric motors. The outfit was installed in three freight cars and transported to various terminals for pumping Mississippi flood waters back over the dykes. The combined pumping capacity varied from 17,000 to 20,000 gallons per minute and was particularly advantageous in clearing the Mounds, Ill., Cairo, Ill., and Vicksburg, Miss., Yards. Photographs and details are given.—*R. C. Bardwell.*

Effect of Hot Water on Suction Lifts. M. B. MACNEILLE, C. B. WHITE and GEORGE A. HERRMAN. *Railway Eng. and Maint.*, 23: 7, 299-301. Tables and charts show advisable pressure head for pump suction at higher temperatures.—*R. C. Bardwell.*

Size of Supply Pipes for Water Columns. A. B. PIERCE and F. D. YEATON. *Railway Eng. and Maint.*, 23: 10, 444. Chart is given showing discharge through a 10-inch railroad water column with 10-inch and 12-inch supply pipes.—*R. C. Bardwell.*

Santa Fe Develops Water Supplies in the Desert. Anon. *Railway Eng., and Maint.*, 23: 7, 282-287. Between Albuquerque, N. M., and San Bernardino, Calif., the Coast Lines of the Santa Fe Railroad pass through a semi-arid to absolute desert region. Impounded or shallow well water supplies are not practical and recourse to wells up to 2300-feet deep is necessary. Air lifts are largely used, driven by Diesel type engines up to 180 h.p. In several cases, such as at Grand Canyon, where heads are excessive for practical pumping, water is hauled. Most of the water secured requires treatment. Standard steel treating and settling tanks are 24 feet by 60 feet and 48 feet by 60 feet. Diagrams and photographs of typical installations are shown.—*R. C. Bardwell.*

The Mississippi Valley Flood—1927. Comp. Rep. A. F. BLAESS, Chairman. American Railway Engineering Association Bulletin 297: 96; *Railway Age*, 83: 12, 511-515. This report includes complete description and statistics on the record flood in the Mississippi Valley with reference to effect on railways. Total loss approximates \$10,000,000 and operation was suspended from 10 to 120 days on 3,000 miles of line. Detailed summary of conditions on the C. C. & St. L. Ry., Ill. Cent. RR., C. R. I. & P. Ry., L. & A. Ry., L. Ry., & N. Co., Mo. Pac. RR., N. O. T. & M. R., St. L. & S. F. Ry., and T. & P. Ry. is given together with photographs showing results. Damage is summarized.—*R. C. Bardwell.*

Joint Committee Presents Report on Drinking Water. Anon. *Railway Age*, 83: 11, 475-6. *Railway Engineering and Maintenance*, 23: 9, 367. Joint Committee of American Railroad Association presents recommendations on handling of ice and drinking water for patrons and employees.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

A New Treating Plant for Locomotive Water Supplies. Anon. *Railway Age*, 83: 5, 213, *Railway Engineering and Maintenance* 23: 7, 303. Feature of new device consists in forcing chemical solution into roadside tank from diaphragm drum proportionately with flow of raw water by restricting discharge line to obtain water on opposite side of diaphragm in the drum. Diagram and standard dimensions are shown.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

Preventing Incrustation of Pipe Lines in Lime-Soda Treatment. WILLIAM M. BARR and H. W. FAUS. *Railway Engineering and Maintenance*, 23: 6, 257. Municipal practice of introducing CO_2 into the treated water is not practical for steam plant service. Sodium aluminate appears to give best results.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

Cutting the Cost of Water Treatment \$2.27 per 100,000 gallons. C. R. KNOWLES. *Railway Engineering and Maintenance*, 23: 5, 211. Illinois Central Railroad claims to have reduced the treatment expense by recovering filter wash water and less sludging loss with conical bottom tank. Construction details for chemical apparatus, housing, and pressure filter are shown.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

Santa Fe Develops Water Supplies in the Desert. Anon. *Railway Engineering and Maintenance*, 23: 7, 282-287. Scarcity of available water supply through semi-arid and desert region between Albuquerque, N. M., and San Bernardino, Calif., requires use of wells up to 2300 feet deep. The quality is mostly bad, carrying as high as 53 grains per gallon incrusting solids and 90 grains per gallon total dissolved solids. Standard treating and settling tanks are 24 feet diameter by 60 feet high and 48 feet diameter by 60 feet high. Water is chlorinated where used for municipal purposes. Diagrams and photographs are shown.—*R. C. Bardwell (Courtesy Chem. Abst.)*.

The Water Supply of Maastricht. A. H. VAN DE VELDE. *Verslagen en Mededeelingen betreffende de Volksgezondheid*, 1926, 7, July, 1926 pp. 828-834. The circumstances leading up to the adoption of the new supply, in use since November, 1925, and officially taken over in April, 1926, are reviewed. In February, 1923, the former supply was found to be contaminated. An investigation by the Central Laboratory confirmed the unfavorable results, water in the wells as well as from the tap being *B. Coli* positive in 10 cc. The wells were in gravel beds 12.14 meters deep yet apparently subject at high water stages to pollution from the Maas. Their situation, too, in a partly agricultural village with the usual undrained manure heaps, etc., exposed them to very serious risk of surface contamination. This was actually proved by percolation experiments with salt and with lithium compounds, as a result of which

the supply, though ample, had to be condemned on hygienic grounds. The wells at Amby were then bored and tested for 2½ months and found to give good water in ample supply. As from August, 1923, until the new supply became available the old supply was made safe by chlorination. Dosage ranging from 0.05 to 0.1 p.p.m. was found effective. Although no publicity was given to the chlorine installation, complaints of taste were at first frequent, perhaps because of the initial higher dosage (0.2 p.p.m.), and were a factor in the readiness to embark on the new supply for which chlorination is unnecessary. A source of supply intrinsically safe is considered to be in many respects preferable to a doubtful source rendered safe by chlorination. The new supply has been shown to be in no danger of pollution from high water stages in the Maas.—*Frank Hannan.*

Abbreviated Report of the Government (Holland) Water Supply Bureau for 1925. Ibid., pp. 649-723. A short account of the rural supply projects inaugurated and in course of inauguration under the Bureau's auspices, outlining the many and various difficulties with which such undertakings have to contend. The manifold functions of the Bureau include, for example, technical advice on such matters as deferrization and demanganization. The Government is keenly alive to the desirability of providing reliable water for the rural, no less than for the urban population. In more prosperous times it even participated financially in certain approved projects and even now is prepared to assume in some cases a certain contingent liability. Upon the Bureau rests the responsibility of seeing that these rural supply projects are established upon the soundest possible basis, both technically and financially. Activities to this end are summarized under 93 headings. Perhaps the greatest difficulty to be surmounted is that of popularizing the idea of paying for water among the thrifty and independent Dutch. Some of the propaganda work is described. In an appendix, Engineer MARKUS of the Bureau lists for 94 Dutch waters the hardness as deduced by the application of certain formulae from the electrical conductivity and the hardness as found by analysis. Agreement is moderately satisfactory.—*Frank Hannan.*

Investigation of the Spring Water Supply of Batavia. Engineer C. P. MOM. Mededeelingen van den Dienst der Volksgezondheid in Nederlandsch-Indië, 1926, IV, 309-337. From 1843 until 1922 Batavia was supplied with artesian water; in 1922 the present supply from the Tjiomas springs came into use. The springs are about 53 km. from Batavia in hilly country 270 m. above sea level in a barbed wire enclosure of about 15,000 square meters. They are quite numerous, with a combined flow of about 500 liters per second, of which about 350 liters per second are now being collected. Preliminary examination indicated a water of great purity and of probable deep origin. The bacteriological quality of the supply when taken into use fell short of expectation; hence a long and careful investigation which well exemplifies the inherent difficulties of collecting safely a spring supply, especially in tropical countries. A long and very valuable discussion of the interpretation of bacteriological findings and of its limitations is given with reference more especially to tropical conditions. Great weight is attached to the important discoveries

of STILES and CROHURST with regard to underground migration. It was proved that in the plan originally adopted for collecting the spring water the exclusion of surface drainage was not complete. Neither was it feasible, in the very difficult local conditions to exclude absolutely the very abundant sub-surface water flowing down the Tjiomas valley, except at prohibitive cost. Judicious alterations have, however, reduced the invasion of extraneous water to negligible proportions and chlorination has been added; the final result being an absolutely reliable and satisfactory water.—*Frank Hannan.*

Water Purification at Richmond. WELLINGTON DONALDSON and FRANK O. BALDWIN. *Public Works*, 58: 241-5, 1927. The supply is taken from the James River and is treated, filtered and aerated in a modern purification plant of 30 m.g.d. capacity. Operating difficulties have been experienced due to sulphite wastes from pulp and paper mills, which during low river stages require the use of larger doses of alum and chlorine. The efficiency of the filter is impaired due to the sticky discolored material resulting from coagulation.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Water Supplies and Fire Protection. J. H. HOWLAND. *Water Works*, 66: 346-7, 1927. Two outstanding qualities for a water works from the standpoint of fire protection are adequacy and reliability. The flows required for adequate protection vary with the structural conditions and population from 500 to 600 g.p.m. for communities with small low scattered buildings up to 12,000 g.p.m. for congested value districts in cities of 200,000. The hydrants must be spaced so that the requisite number of streams may be properly concentrated. Pumping stations should be thoroughly safeguarded to insure continuity of service and the storage of water in elevated tanks beyond pumps is an important feature for any system.—*C. C. Ruchhoft.*

Prevention of Corrosion in Steel Pipe Line. WALTER KIRKWOOD WELLER. *Water Works*, 66: 342-3, 1927. To prevent corrosion in a 350-mile 30-inch-steel pipe line carrying water from Mundaring to Kalgoorlie in Western Australia a deaerator (capable of treating 6 million gallons of water per day) was installed at the Mundaring reservoir. In this deaerator, which is described in detail, the water is allowed to fall into a chamber containing two perforated plates 4 feet 6 inches apart, the upper plate containing 2760 holes $8\frac{1}{2}$ inch in diameter and the lower plate 7500 $\frac{1}{4}$ -inch holes. The upper part of this water chamber is connected with a gas receiver in which a vacuum of from 28 to 28.5 inches of mercury is maintained by steam driven vacuum pumps. The ratio of vacuum pump piston displacement to the volume of water being treated when 4 million gallons of water per day are passing through the deaerator and the vacuum pump is running at 120 r.p.m. is 1.3. The dissolved oxygen is reduced from between 8 and 10 p.p.m. to from 0.7 to 1.0 p.p.m. and it was found that in the first thirty miles of flow the residual dissolved oxygen entirely disappeared. Seven pumping stations are used to pump this supply to Kalgoorlie where the main terminates and about one half of the water is used. The remainder of the supply is drawn off en route into tanks to supply agricultural towns and districts. In order to prevent reaeration, the water in the pipe line is bypassed around these tanks.—*C. C. Ruchhoft.*

New 20-inch Well at Benson, Minn. THEO. K. LEE. *Water Works*, 66: 360, 1927. Two old 8-inch wells produced only 165 gallons per minute which was insufficient for the town and therefore a new 20-inch well was drilled. The casing of the new well was lowered to a depth of 141 feet and a screen 30 feet long was lowered into the water bearing sand and gravel section. The well produced 520 gallons per minute under test and is being pumped by an air lift pump. The new well taps the same water bearing strata and is only 65 feet from the old wells.—*C. C. Ruchhoft*.

Operation and Control of Rapid Sand Filters. S. T. POWELL. *Water Works*, 66: 361-3, 1927. *Public Works*, 58: 266-8, 1927. Practical suggestions are given for overcoming many of the difficulties encountered in the operation of rapid sand filter plants. Irregular plant operation is more often the result of faulty chemical feed than of any other single cause. Proper maintenance of sand beds is important, and mud ball formation is detrimental. Troubles due to air bound filters may be relieved by frequent short back washing. The opening and closing of all valves slowly is requisite for the safety of the sand beds and the underdrainage system. The importance of controllers and gauges is pointed out, and the following determinations and records are suggested as necessary for an efficiently operated plant: alkalinity, turbidity, hydrogen ion concentration, temperature (air and water), volume of water treated, and amounts of chemicals used.—*C. C. Ruchhoft*.

Filter Plants of Low Cost of Construction and Operation. J. H. FUERTES. *Water Works*, 66: 364-6, 1927. The filter plant at Steelton, Pa., which consists of three roughing filters, containing five feet of crushed anthracite coal, and a covered slow sand filter has an operating cost of \$7.21 per m.g. The Denver plant of 64 million gallons per day capacity is of the rapid type with five foot deep filter beds of anthracite coal. The construction cost of this plant was \$26,000 per m.g.d. and the total operation cost \$9.75 per m.g.—*C. C. Ruchhoft*.

Zeolite Water Softeners for Domestic Use. W. C. HIRN and E. F. ELDRIDGE. *Muni. & County Eng.*, 71: 29-31, 1926; *Public Health (Mich. Dept. of Health)*, 14: 137-40, 1926. A short historical sketch of the discovery of the base exchange minerals and a discussion of their use in water softening is given. The mechanical arrangements for a satisfactory household zeolite water softener are described and it is estimated that the cost of a household softener will compare favorably with the cost of a rain water cistern soft water supply.—*C. C. Ruchhoft (Courtesy Chem. Abst.)*.

The Water Supply of Tryon N. C. GEO. W. WHITE. *American City*, 37: 4, October, 1927. Description of a small rapid sand filtration plant.—*Chas. R. Cox*.

High Efficiency Developed in Detroit Water-Works Pumps. *American City*, 37: 4, October, 1927. Description of 50 m.g.d. and 70 m.g.d. centrifugal pumps driven by synchronous motors having overall efficiencies of 84.7 per cent and 82.7 per cent respectively.—*Chas. R. Cox*.

The New Filtration Plant at Ronceverte, W. Va. American City, 37: 3, September, 1927. Description of modern rapid sand filtration plant for city of 2300.—*Chas. R. Cox.*

The Recent Typhoid Epidemic in Grafton, W. Va. American City, 37: 3, September, 1927. Twenty-five deaths from 150 cases of typhoid fever resulted when a seriously polluted mountain stream was improperly treated by a partially disabled chlorination apparatus under inadequate supervision. A previous bond issue for a filtration plant was defeated and the chlorination plant was installed only after energetic action by the State Department of Health. A full-time health officer had been removed sometime previously by the County Court as an economy measure, so routine examination of samples of water had to be discontinued. A modern filtration plant is being designed as the result of this unfortunate object lesson.—*Chas. R. Cox.*

Air-made Wells for Water Supply, Chandler, Okla. WEBSTER L. BENHAM. American City, 37: 4, October, 1927. An inadequate well supply utilizing inefficient deep well pumps was replaced by a new supply consisting of four "air-made" wells of the gravel wall type and air-lift pumping equipment. The new equipment effectively increased the yield from an unpromising water bearing stratum.—*Chas. R. Cox.*

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